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TECHNIQUES FOR ESTIMATING HIGHWAY TRUCK VOLUMES

by

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EXECUTIVE SUMMARY

Trucking is the most important mode of transport for commodities in the Province of Ontario. There are approximately 750,000 trucks registered in the Province and some 500,000 trailers. It is estimated that there are some 10 million truck movements annually on the major highway network involving some 4,000 million kilometres of travel. Total commodity movements by truck within the Province on the major elements of the Provincial highway system are estimated to be of the order of 120 million tonnes annually. Truck volumes along the Highway 401 corridor vary from about 23,000 per day within Metropolitan Toronto to 3,000-4,000 per day at the extremities of this corridor. Existing and expected highway truck volumes have significant implications for the provincial highway program delivery in terms of: (i) long-range and priority planning; (ii) traffic operations and capacity; (iii) traffic safety and regulation; (iv) environmental impact studies; and (v) geometric, pavement and structure design.

Fabricated materials including motor vehicles and parts, crude non-metallic minerals, end products, food and beverages represent the major commodity groups carried by trucks. For-hire trucks capture a larger proportion of the commodity movement market than private trucks, except for a few of the commodity types such as food, beverages and wood fabricated materials. The rail mode carries a larger share of intra-provincial commodity movements only for crude materials moved over relatively long distances. Forecasts of future trucking activity suggest an annual growth rate in tonnes shipped by for-hire trucks of about 3.4 percent throughout the 1980s.

The overall goal of the study described in this report is to establish a better understanding of truck movements within Ontario. The specific objectives of the study include the development of a technique for estimating future average daily truck volumes on the principal links of the Provincial highway system, and the identification of an appropriate on-going data collection effort.

Truck movements are simply a consequence of the commodity movement patterns that exist in the Province, and these reflect the patterns of production and consumption. While the per capita final

demand by households may not vary substantially across the Province, the per employee commodity inputs vary widely between industry types. For example, asphalt roofing plants consume about 1,200 tonnes of input material per employee, truck body and trailer plants 980 tonnes per employee and communications equipment plants only about 1.3 tonnes per employee. Clearly, structural changes in the Provincial economy will have important impacts on the patterns and intensities of truck movements. Truck movement patterns within the Province are dictated by the particular patterns of inter-industry linkages, rather than by some simple law of spatial interaction decay with increasing spatial separation.

Four broad approaches to the problem of estimating future highway truck volumes may be identified and these are: (i) an input-output model is used to predict commodity flows which are then converted into truck movement demands using a modal split model; (ii) an adaptation of the multi-stage approach used in urban transport planning; (iii) a growth factor approach in which the existing spatial interaction structure is used as the basis for estimating future demands; and (iv) a growth factor approach which uses information on link flows to estimate future demands. These alternatives are assessed with respect to a number of criteria which include scientific integrity, data requirements, relevance to MTC analysis requirements, development time and costs. It has been concluded that a growth factor approach which relies on a sample of truck origin to destination movements is most appropriate at this time to achieve the objectives of MTC. The necessary data may be collected relatively cheaply, and the analytical method is fairly simple and transparent.

The growth factor approach relies on the development of a log-linear model of an observed set of transport flows. A particular truck movement magnitude between an origin and destination may be decomposed into four types of effects and these are: (i) an overall effect reflecting the total number of trips in a system; (ii) an origin effect reflecting the relative intensity of trip generation; (iii) a destination zone effect reflecting the relative intensity of

trip attraction; and (iv) the pure interaction effects between two zones reflecting the strength of inter-industry linkages between these zones. This approach is similar to the analysis of variance paradigm of statistics, and the traditional gravity model in its various forms represents a special case of this general approach.

Future origin to destination magnitudes are estimated by adjusting the interaction effects extracted from the survey data to a new set of generation and attraction magnitudes estimated by the time horizon of interest, using bi-proportional balancing procedures. Expected changes in the interaction structure may be incorporated into the interaction matrix before it is adjusted to the future generation and attraction magnitudes.

Two basic data sets on the origin-destination patterns of commodity and trucking movements exist for Ontario. Statistics Canada has conducted a survey of commodity movements by for-hire trucks since 1973 with the most recent data set available being for 1979. An origin-destination survey of trucking movements was conducted by MTC in 1978 at the highway inspection stations and this survey provides information on commodity types carried, private/for-hire truck split, truck capacity used and so on, in addition to truck movement information. Generation and attraction rates have been established for both of these data sets along with estimates of the interaction structure.

A review of the commodity attraction and generation magnitudes estimated by the Statistics Canada survey from 1973 to 1979 showed substantial year to year variations. For example, between 1974 and 1975 commodity attractions to Thunder Bay increased by 522 percent; between 1977 and 1978 attractions to Kitchener increased by 135 percent. While some of these abrupt year to year changes may be explained by the survey sampling error, the case of Thunder Bay raises an issue about the reliability of the survey. The estimated sampling error is also rather large, with many of the population centres having coefficients of variation for generations and attractions of greater than 20 percent.

Estimates of the annual commodity movements by for-hire trucks obtained in the Statistics Canada survey are coded to the ten major population centres of Ontario. Regression analyses of this data set to establish generation and attraction rates are severely restrained by the small number of spatial units and the restricted number of independent variables. The three principal variables available for the ten major population centres are population, total trucks registered and the number of manufacturing man-hours by industry sector. Analyses of the inter-relationships between these three variables showed that they are highly inter-related statistically, principally because of the large spatial units that had to be used. The only substantial deviation in these pairwise comparisons of the independent variables was for Ottawa, which had a substantially lower than average per capita amount of manufacturing man-hours, an expected result.

Because of the dominance of the for-hire inter-city trucking market by manufactured commodities a variety of regression equations were estimated and evaluated in an attempt to relate commodity attractions and generations to the manufacturing composition of each area. Only two reasonable equation forms emerged from these analyses and these were in terms of total manufacturing man-hours, and manufacturing man-hours stratified into light and heavy industry. Analyses of the 1974-1978 survey data suggested a commodity attraction rate of 0.025-0.032 tonnes per man-hour worked, and a commodity generation rate of 0.024-0.029 tonnes per man-hour worked. While the regression equations had very good overall statistical qualities, substantial residuals existed for selected communities. Most of the residuals could be related to the atypical characteristics of the Ontario communities, such as Ottawa with its low proportions of manufacturing employment, and Hamilton with its large concentrations of heavy manufacturing.

Commodity attraction and generation equations were also developed in terms of truck registration, and population, with little change in the explanatory powers from those developed in terms of manufacturing man-hours. If the for-hire trucking data were coded to a finer spatial system

without significant losses in statistical reliability, then improved prediction equations with a richer array of independent variables might be developed. With the present system of ten population centres only broad statistical associations between the aggregate sets of variables can be developed. It has been concluded that the large standard errors associated with these prediction equations restricts very severely their use in forecasting.

The commodity flow tables for total commodity movements, and movements for the two principal commodity groups moved by for-hire trucks have been analyzed in order to extract the pure interaction effects between the major population centres. A bi-proportional balancing procedure was used to establish the interaction matrices. The entries in these matrices represent the probabilities of commodity shipment interactions between two areas that are independent of the actual sizes of the communities. Cluster analysis has been used to isolate similarities in the shipping destination patterns of the population centres. The important conclusion that emerged from this analysis was that the commodity shipment interaction patterns in Ontario are strongly related to inter-industry linkages rather than to some simple spatial interaction hypothesis such as the rate of interaction decays with increasing spatial separation.

Data obtained in the 1978 MTC commercial vehicle survey was aggregated to the same spatial scale as the Statistics Canada survey. Truck trip attraction and generation equations have been developed in terms of population and these equations have good overall statistical qualities but with some significant residuals. Truck trips associated with population centres with strong industrial bases tend to be underestimated, while the over-estimation residuals are associated with weak manufacturing employment bases, and in the case of Thunder Bay, with higher proportions of shipments by rail.

The bi-proportional balancing/cluster analyses of the MTC data were performed separately for the for-hire, private and total truck flow matrices. These analyses demonstrated that the destination probability vectors were more homogeneous for the eight population centres in Southern Ontario than those observed for the Statistics Canada data. The destin-

ation vectors for private trucking were more heterogeneous than for the for-hire trucking, reflecting no doubt, the restricted mix of commodity types carried by private trucking. Comparisons of the interaction probabilities for for-hire trucks extracted from the MTC survey with those obtained from the Statistics Canada survey showed little statistical association. The MTC interaction patterns must be regarded as a more representative sample because of the larger sample size.

Generations and attractions obtained in the MTC survey have also been analyzed at the finer spatial scale to which the data were originally coded. Regression equations with high statistical qualities have been developed in terms of the population of the centres with the principal under-estimation residuals being associated with those communities containing automobile production lines and other high throughput manufacturing industries. Stratified employment data are not available at this spatial scale and more sophisticated prediction equations could not be tested.

The proposed forecasting approach may be implemented by identifying movement strata based on the stages of the production-consumption cycle where the major groups would be natural resource movements, inter-industry movements, and movements to final demand. A very coarse major commodity group classification could be used within each of these major strata.

A two-stage survey may be used to establish the necessary rate and interaction data required to implement the forecasting method. The first stage would involve an inspection station-based survey to establish the broad dimensions of the movement strata in each major geographic sector of the Province. A place of generation survey would then be conducted within the sampling frames defined by the first stage in order to establish a detailed understanding of truck movement rates and interaction patterns.

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CHAPTER 1

TRUCK TRIP TRAVEL IN ONTARIO

1.1 Trucking Characteristics

In 1980 there were some 778,000 trucks of all types registered in Ontario along with some 520,000 trailers. The 1978 commercial vehicle survey conducted by the Ontario Ministry of Transportation and Communications suggested that there were 9.8 million truck movements on the major highways in Ontario in 1978. The average truck trip distance observed in this survey was 400 km, indicating a total truck movement of 3,920 million kilometres.

Figure 1.1 illustrates the estimated average daily truck volumes along the Highway 401 corridor in 1978. The diagram shows that the average daily truck volumes varied from about 11 percent of the average daily traffic volume within Metropolitan Toronto to about 30 percent in Eastern Ontario. The absolute flow magnitudes were highest within Metropolitan Toronto and on the sections of Highway 401 immediately to the east and to the west of the Metropolitan Toronto region.

1.2 Commodity Movements by Truck

Truck movements are a consequence of the economic activities of production and consumption. Within Ontario the bulk of the primary and secondary products are carried either by for-hire or private trucks. While the character of commodity movements by truck is not well understood, several recent surveys have provided some understanding.

Statistics Canada has surveyed commodity movements by for-hire trucks since 1973 and Figure 1.2 provides an indication of the broad commodity groups moved in Ontario in 1978. The diagram illustrates that about 40 percent of the total shipments in 1978 consisted of fabricated materials, with shipments of crude materials and inedible end products

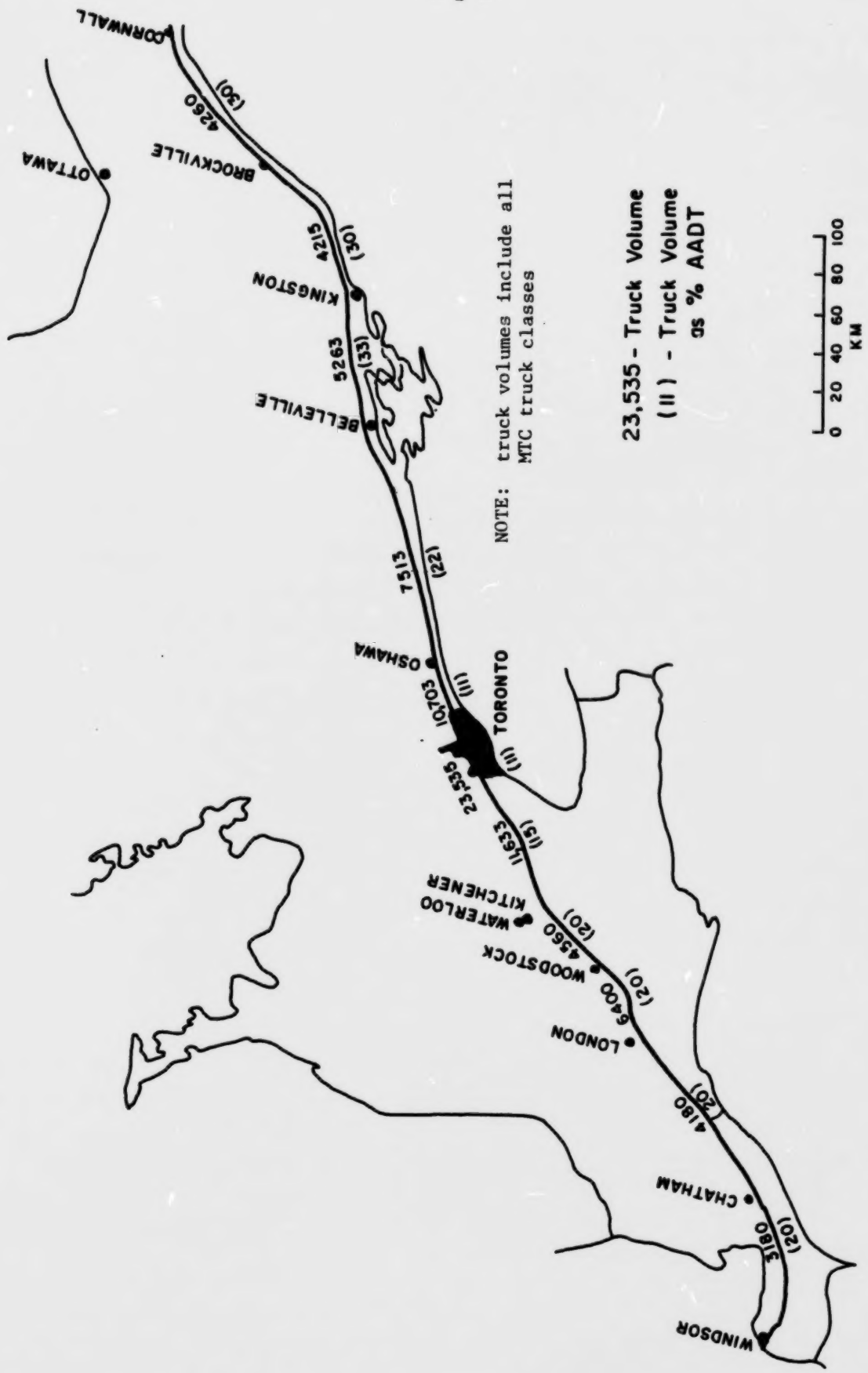
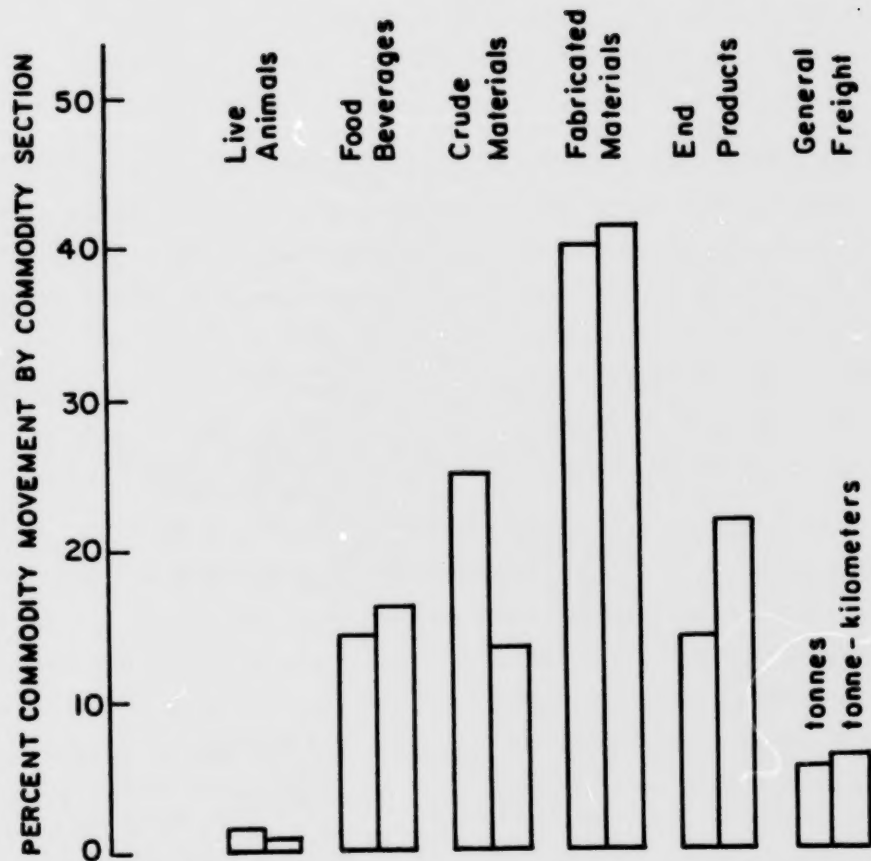


Figure 1.1 - Estimated Average Daily Truck Volumes Along the Highway 401 Corridor, 1978



Source : Statistics Canada (1980) , For-Hire Trucking Survey , 1978 . Cat . 53 - 224

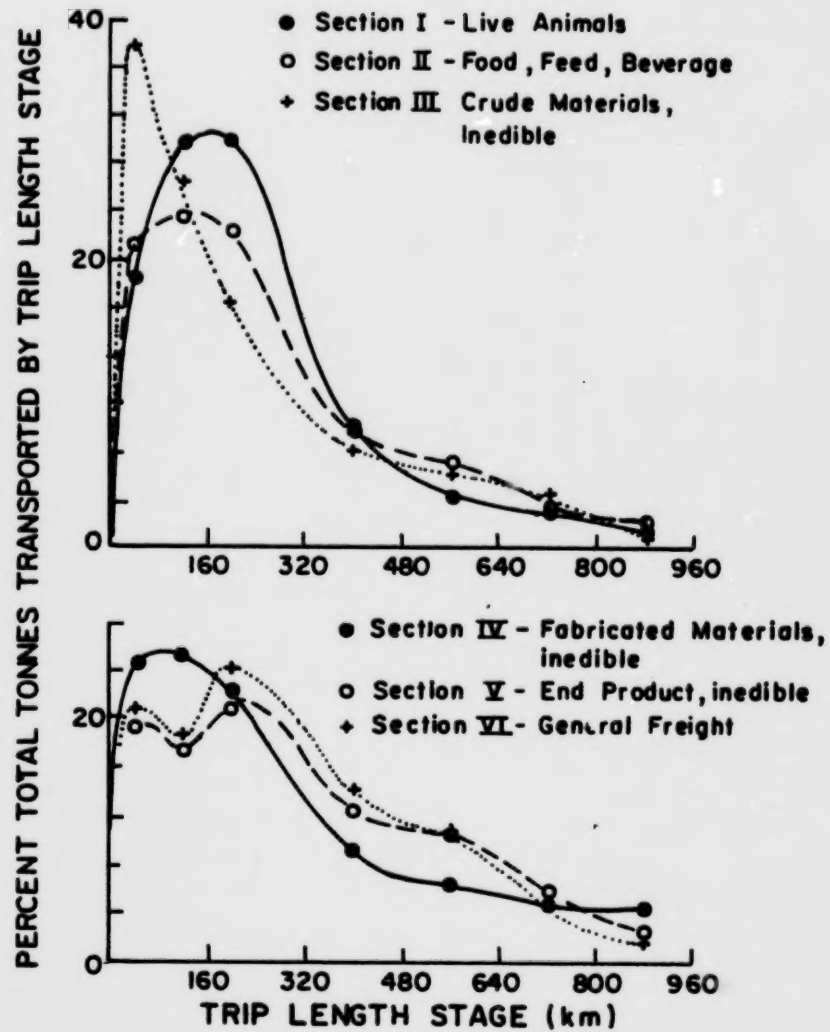
Figure 1.2 - Commodity Movements by For-Hire Trucking by Major Commodity Section, Ontario, 1978

representing the next highest proportions. Figure 1.2 also illustrates that some differences in magnitude exist between tonnes shipped and the tonne-kilometres resulting from these movements. Crude materials were shipped over shorter than average distances while end products were shipped over longer than average distances. Figure 1.3 reflects these differences in shipment distances between commodity groups more precisely in terms of characteristic trip length frequency distributions.

Information on the character of commodity movements by trucks has also been obtained in truck inspection station based surveys conducted by the Ontario Ministry of Transportation and Communications. Figure 1.4 illustrates the observed percentage of truck movements classified by the ten most frequently carried commodity groups by for-hire and private trucks. While a more stratified commodity classification has been used, the proportions are compatible with those illustrated in Figure 1.2 with fabricated products representing the largest commodity movement group.

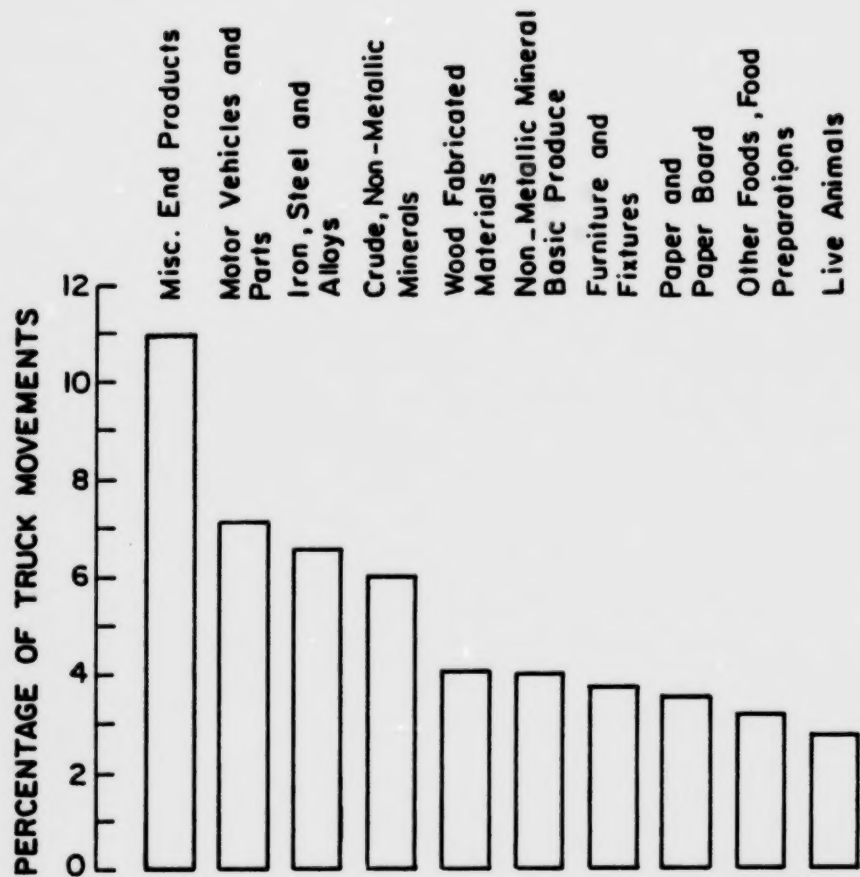
It is interesting to note that the Statistics Canada survey estimated that 69,000,000 tonnes of commodities were shipped by for-hire trucks between the ten major population centres of Ontario in 1978. The MTC Survey indicated that 59 percent of the total commodity shipments by weight were by for-hire truck, suggesting a total movement by both private and for-hire trucks of 117,000,000 tonnes. The MTC survey suggested a total commodity movement on major Ontario highways in 1978 of 111,000,000 tonnes, a difference of about 6.0 percent.

The Ontario MTC survey also provided some information on the proportions of the truck shipment market captured by the for-hire and private truck fleets. Figure 1.5 illustrates the proportions of the ten major commodity groups shipped by for-hire and private trucks in terms of the number of truck movements observed. While for-hire trucking tends to dominate for most commodity groups, private trucking accounted for the larger proportion of movements for wood fabricated materials and other food products. Fifty-one percent of all truck movements observed in this survey were private trucks.



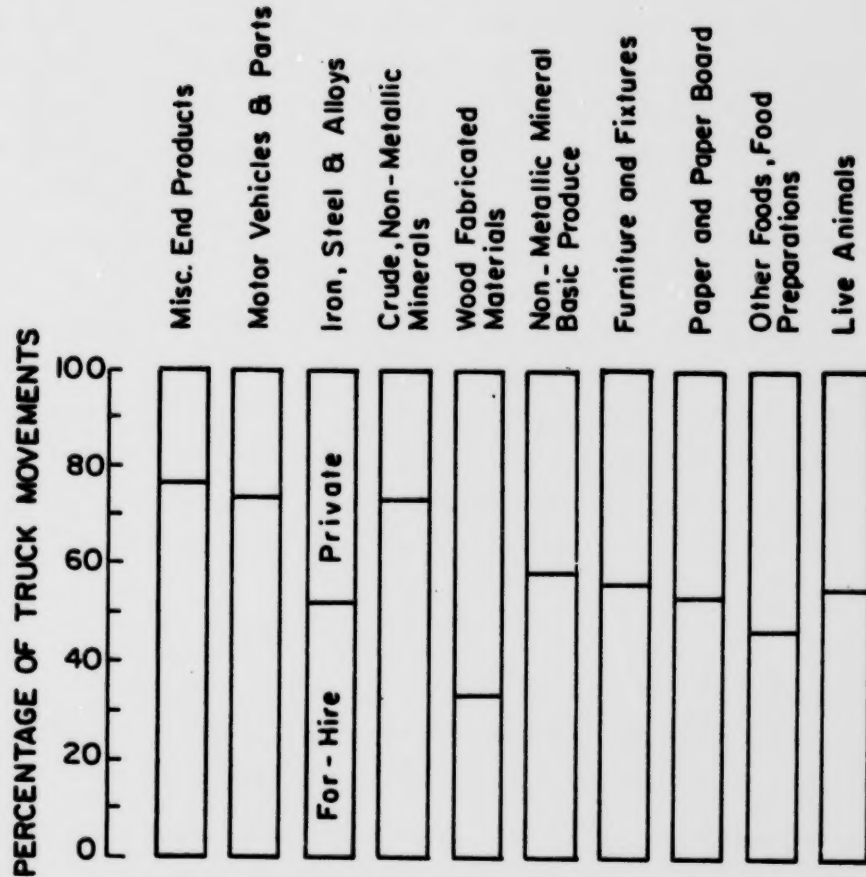
Source: Statistics Canada (1980), For-Hire Trucking Survey, 1978. Cat. 53-224

Figure 1.3 - Distribution of Commodity Tonnes by Distance Blocks by Commodity Section, 1978



Source: Economic Policy Office (1980) Ontario Commercial Truck Survey 1978, Ministry of Transportation and Communications, Ontario

Figure 1.4 - Ten Most Frequently Carried Commodity Groups by For-Hire and Private Trucks



Source: Economic Policy Office (1980). Ontario Commercial Truck Survey, 1978. Ministry of Transportation and Communications, Ontario.

Figure 1.5 - For-Hire/Private Truck Split for Ten Top-Ranking Commodity Groups

1.3 Forecasts of Future Trucking Activity

Transport Canada (1981b) has published recently forecasts of freight and passenger travel demands to 1991. Forecasts of the for-hire trucking demand have been developed using the Statistics Canada for-hire trucking surveys. The results of the time series analyses are summarized in Table 1.1 for the five major regions of Canada. The table indicates that Ontario and Quebec will continue to dominate the trucking industry originating some 100 million tonnes of freight by for-hire trucks in 1990. An average annual growth rate of 3.4 per-cent between 1978 and 1990 is expected, less than the forecast growth of the manufacturing sector in these two provinces. It is interesting to note at this point that the Transport Canada analyses suggested a strong correlation between for-hire truck loadings and manufacturing output, and between for-hire truck unloadings and total output (con-sidered a proxy for demand).

1.4 Objectives of the Study

The broad goal of the study described in this report is to establish a better understanding of truck movement patterns in Ontario. The specific objectives established for the study are:

1. To establish a conceptual framework within which the study of truck movements on the Ontario highway system may be considered, and to use this framework to identify the economic forces generating truck movements.
2. To identify factors that may have a substantial impact on the volume and structure of truck movements in Ontario.
3. To develop a method for estimating future average daily truck volumes by truck type on the principal links of the Provincial highway system.
4. To identify an appropriate on-going data collection effort to support this analytical effort.

TABLE 1.1 For-Hire Truck Flows by Major Region
(millions of tonnes)

<u>Region</u>	<u>Loadings</u>			<u>Unloadings</u>		
	<u>1978</u>	<u>1985</u>	<u>1990</u>	<u>1978</u>	<u>1985</u>	<u>1990</u>
Atlantic	6.9	9.8	12.0	7.3	10.2	12.5
Quebec	23.2	27.0	32.0	23.5	27.0	32.0
Ontario	43.9	57.6	68.0	42.8	56.6	66.9
Prairies	21.3	26.9	34.9	21.3	26.9	34.9
British Columbia ¹	15.7	18.9	23.6	16.0	19.6	24.1
Total	111.0	140.2	170.5	111.0	140.2	170.5

¹ Includes Northwest and Yukon Territories, as economic indicators for British Columbia include the two territories.

Source: Strategic Planning (1981). Transport Canada Freight and Passenger Forecasts. Transport Canada.

1.5 Structure of the Report

Chapter 2 of the report outlines the conceptual framework within which the more detailed analyses of the subsequent chapters are developed. Chapter 3 explores alternative estimation approaches and identifies the most appropriate approach to estimating future truck volumes.

Chapters 4 and 5 provide detailed analyses of the Statistics Canada for-hire trucking surveys conducted since 1972. Chapter 4 examines the demand generation rates for commodity movements by for-hire trucks, while Chapter 5 examines spatial interaction patterns.

Chapter 6 provides an analysis of the truck movement data collected in the MTC 1978 commercial truck survey. Comparisons are made between the findings of these analyses and the analyses described in Chapters 4 and 5.

Chapter 7 outlines the other sources of information on Ontario truck movements available and provides some analyses of this information.

Chapter 8 outlines the proposed forecasting framework and the associated data collection surveys, while Chapter 9 describes the conclusions and recommendations.

CHAPTER 2

A CONCEPTUAL FRAMEWORK

2.1 Introduction

Figure 2.1 attempts to identify the principal factors influencing truck movements in Ontario in a conceptual sense. The upper left-hand side of the diagram identifies those factors influencing the demand for trucking while the upper right-hand side identifies those factors influencing the supply of trucking. Truck movement patterns by the for-hire and private fleets are viewed as a consequence of the interaction between demand and supply. The truck transport costs and level of service characteristics emerging from these movement patterns are viewed as having an impact on the transport mode choice decisions of commodity shippers.

2.2 Demand Factors

In the upper left-hand side of the diagram commodity flows are viewed as a consequence of the economic activities of production and consumption. The commodity movement demands created by different types of producers vary widely and Table 2.1 provides an indication of the tremendous range of per employee commodity input magnitudes for a variety of Ontario manufacturing industries.

A second feature of commodity flows is that their spatial structure is dictated by the inter-industry linkages, rather than by some simple law relating spatial interaction rates to travel costs. Table 2.2 illustrates part of the Ontario input-output table and shows that the commodity input structures vary widely between industry sectors.

It is well known that trucking captures the bulk of the intra-provincial commodity movement market. Figure 2.2 illustrates this domination for the six major commodity groups with the rail mode only capturing the larger share of the crude materials market, and 23 per cent of the fabricated materials market.

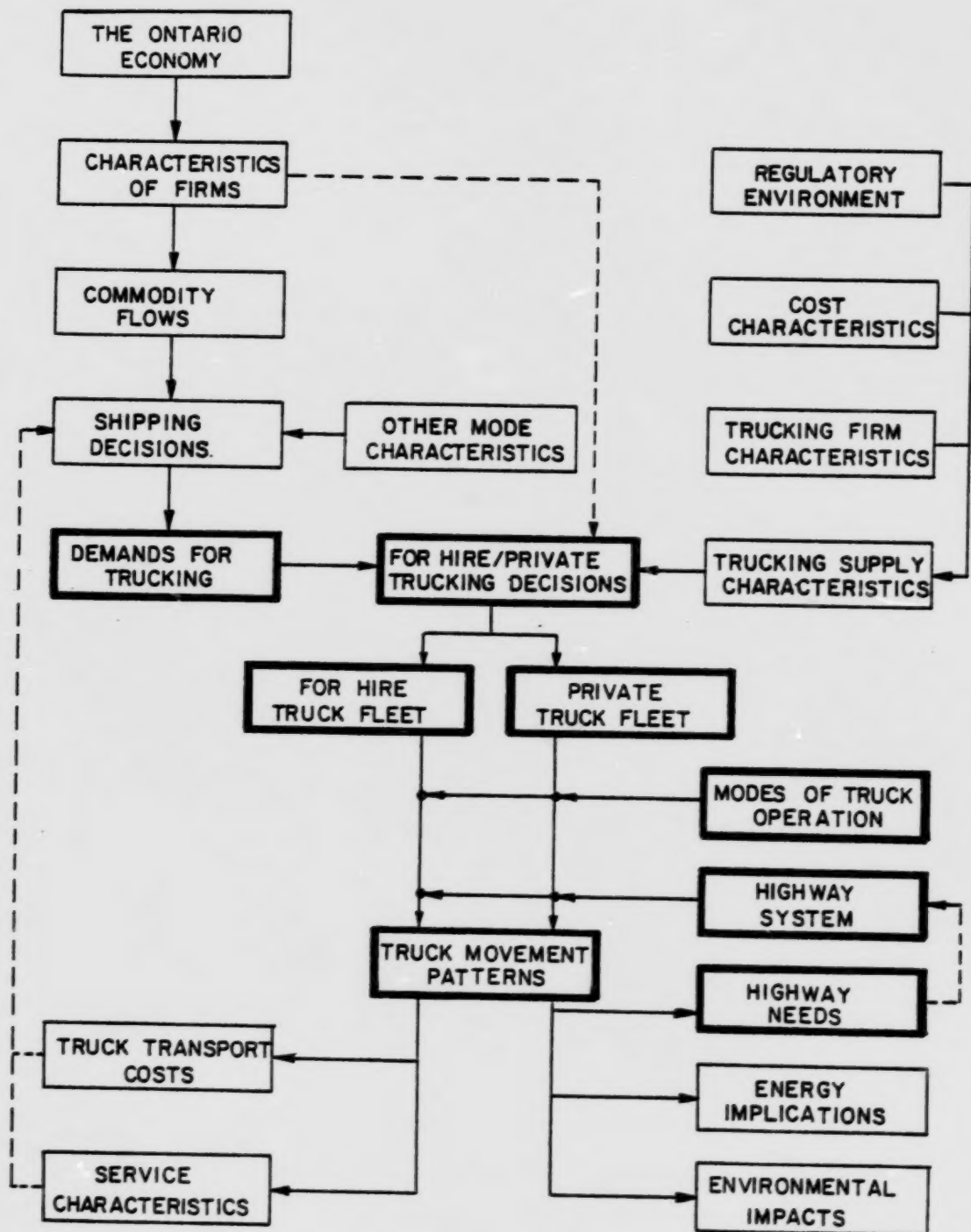


Figure 2.1 - Factors Influencing Trucking Movements

TABLE 2.1 Commodity Inputs per Employee for Various Industry Types, 1979

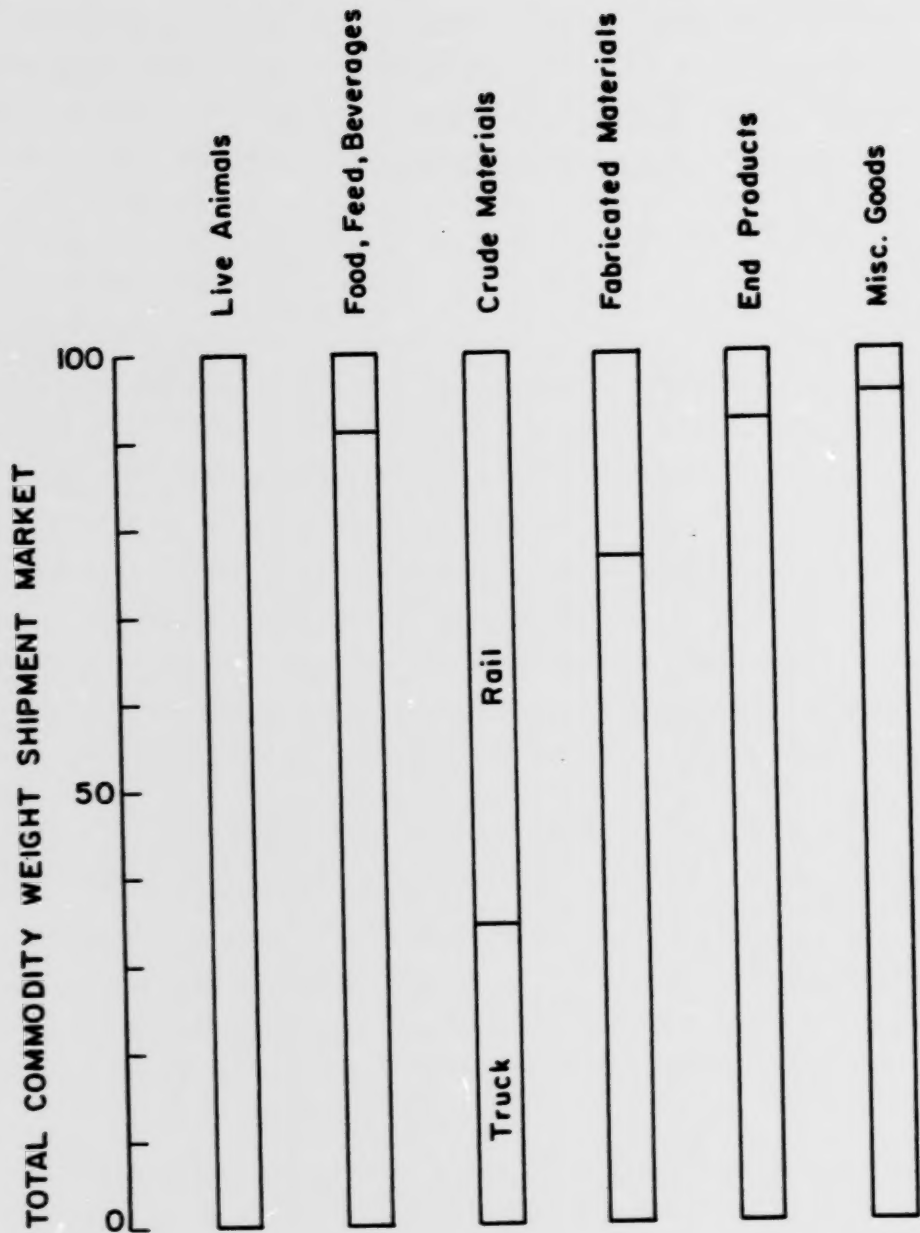
Sector	Annual Input Tonnes/Employee
Aircraft and aircraft parts	2.5
Ship building and repair	12.8
Agricultural implements	159.5
Iron foundries	172.5
Truck bodies and trailer	980.4
Misc. non-metallic mineral products	612.7
Asphalt roofing	1241.1
Fertilizer	2438.8
Pulp and paper	788.3
Rubber products	29.5
Paper and plastic bags	63.6
Communications equipment	1.3
Felt and fiber processing	37.2
Poultry processors	95.1
Flour and breakfast cereal products	892.9
Biscuits	38.6
Confectionary	28.5
Dairy products	36.0
Wineries	243.5

TABLE 2.2 Input-Output Structure of Some Ontario Industries

	31 - Motor Vehicles/Aircraft	33 - Electrical Appliances	35 - Communications Equipment
12 - Rubber Products	.021396	.0	.003936
13 - Leather Products	.000069	.000257	.002584
14 - Cotton Yarn and Cloth	.001164	.0	.0
15 - Synthetic Textiles	.004795	.0	.000712
20 - Furniture and Fixtures	.000064	.000516	.000355
21 - Other Wood Industries	.000434	.002738	.001672
22 - Pulp and Paper Mills	.000433	.000892	.002240
23 - Paper Products	.002904	.038776	.014021
25 - Iron and Steel Mills	.065630	.216819	.038372
26 - Other Primary Metals	.048953	.087807	.199829
27 - Fabricated Metals	.000518	.0	.0
28 - Metal Stamping	.003445	.000128	.000152

Entries represent the value in dollars of outputs produced by the industry sector named at the beginning of each row that are inputs to the industry sector listed at the head of the column per dollar of output produced.

Source: Frank, R. H., et al (1970), "The Input-Output Structure of the Ontario Economy", Ontario Economic Review, Vol. 8, No. 1.



Source : Interdepartmental Committee for the Study of Competition and Regulation in Transportation (1981), Competition and Regulation in Inter-City Trucking Industry in Canada, Ottawa

Figure 2.2 - Modal Shares for Ontario Intra-Provincial Commodity Shipments, 1975-1977 Average

A number of studies of commodity shipping decisions over the past decade have shown that the three dominant factors dictating the choice of a transport mode are: (i) commodity type (reflecting factors such as packing and potential damage costs, inventory costs, etc.), (ii) the annual volume being shipped (reflects average consignment size), and (iii) shipping distance (reflecting trade-offs between pick-up/delivery costs and line haul costs).

Table 2.3 illustrates the estimated influence of shipment size on the rail share of intra-provincial shipment in Ontario for both non-crude and crude materials. It illustrates the sharp increase in the rail share for shipments of greater than 50 tons which is not unexpected given truck loading constraints.

Table 2.4 illustrates the influence of shipment distance on the percentage of total intra-provincial freight tonnage carried by the rail mode. The rail mode captures a larger share than trucking when the shipment distance exceeds 500 miles. However this table must be interpreted very carefully since it includes all commodity groups which have different sensitivities to line haul transport costs.

2.3 Supply Factors

Figure 2.1 suggests that a variety of factors influence the supply side of trucking and these include the regulatory environment, the costs of input factors such as equipment, labour and fuel, and the characteristics of firms in terms of their route structures, size and so on.

A recent federal government study, Interdepartmental Committee for the Study of Competition and Regulation in Transportation (1981), has examined the impact of regulation and competition on the efficiency of the trucking industry. This report observes:

"The preponderance of evidence uncovered to date strongly suggests that carriers operating on the unregulated traffic lanes within Alberta are capable of attaining high profit levels relative to other intra-provincial carriers, and paying high wage rates within the confines of having one of the lowest rate structures within the country."

TABLE 2.3 Estimated Rail Share Tonnage by Shipment Size
in Ontario, 1975-1977 Average

	Shipment Size (tons)			
	0-5	5-20	20-50	> 50
Non-Crude	0	4.8	12.3	80.7
Crude	0	5.0	8.0	97.0

Source: Interdepartment Committee for the Study
of Competition and Regulation in
Transportation (1981)

TABLE 2.4 Estimated Rail Share Tonnage by Shipment Distance
in Ontario, 1975-1977 Average

Shipment Distance (miles)				
0-150	151-300	301-500	501-1000	> 1000
7.7	23.2	38.5	57.0	75.0

Source: Interdepartment Committee for the Study of
Competition and Regulation in Transportation
(1981)

Transport Canada (1981b) has examined the cost structure of the trucking industry and this study suggested that labour productivity in the trucking industry had not kept pace with investments in the industry and that the share of the market obtained by trucks had stabilized.

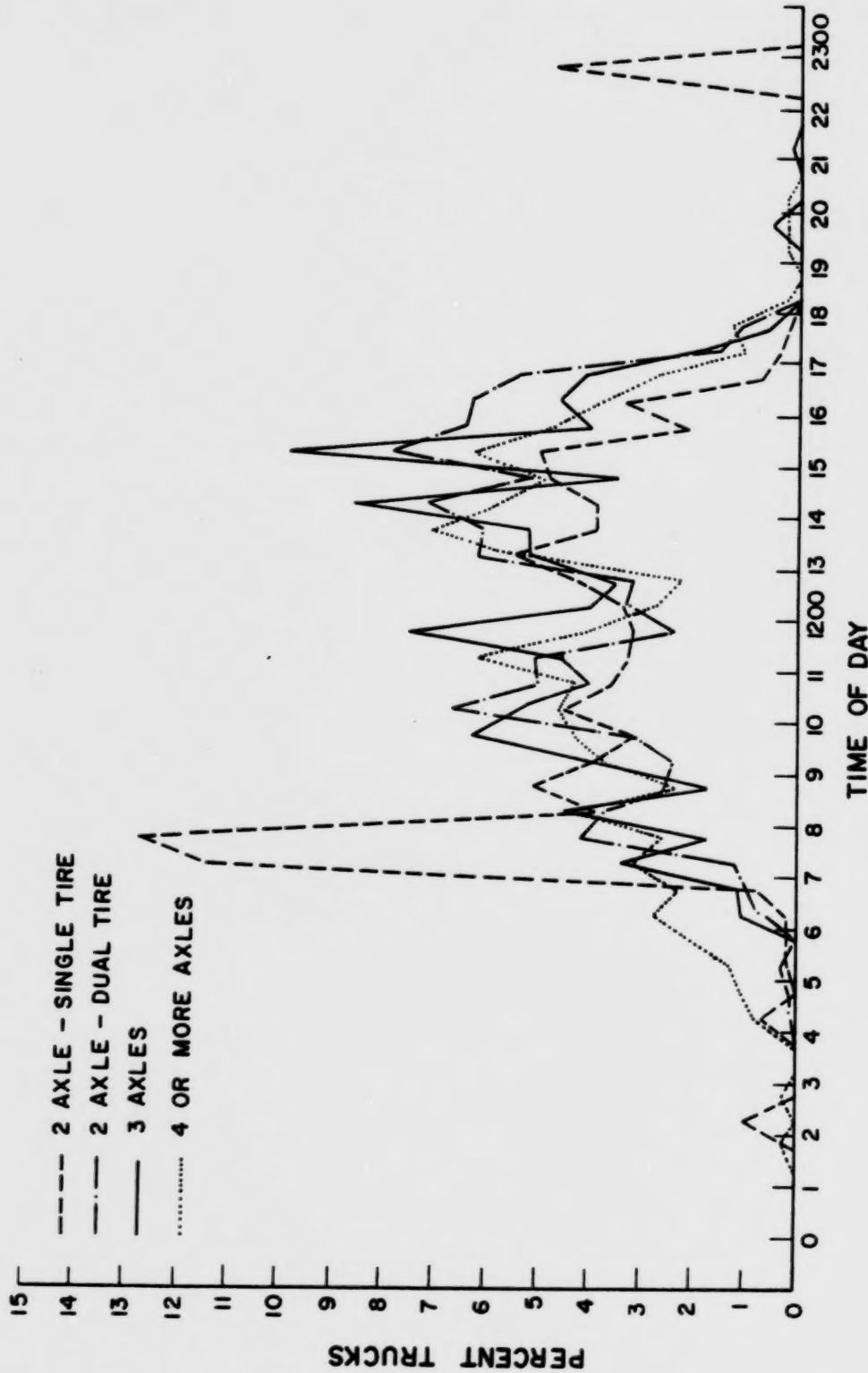
Changing energy costs are also having a major impact on the cost structure of the trucking industry. The inter-city trucking mode is not as energy efficient as the rail mode with energy costs representing roughly 15-20 percent of the operating costs of the truck mode and 8-10 percent of the rail mode. All transport modes are facing significant increases in energy costs but it is expected that the relative costs of the truck and rail modes will not change substantially. There are greater opportunities for improved fuel efficiency with the trucking mode and for shipping distances up to about 1,000 km the inventory, storage and pick-up/delivery costs are still expected to dominate.

The mechanisms governing the split of commodity movements between for-hire trucking and private trucking are understood only in a very general sense. A number of studies have suggested that private trucking is much more important in transporting commodities with low values added including primary products, stone, primary and fabricated metal, petroleum products, food and beverages, Economic Policy Office (1980).

2.4 Modes of Operation

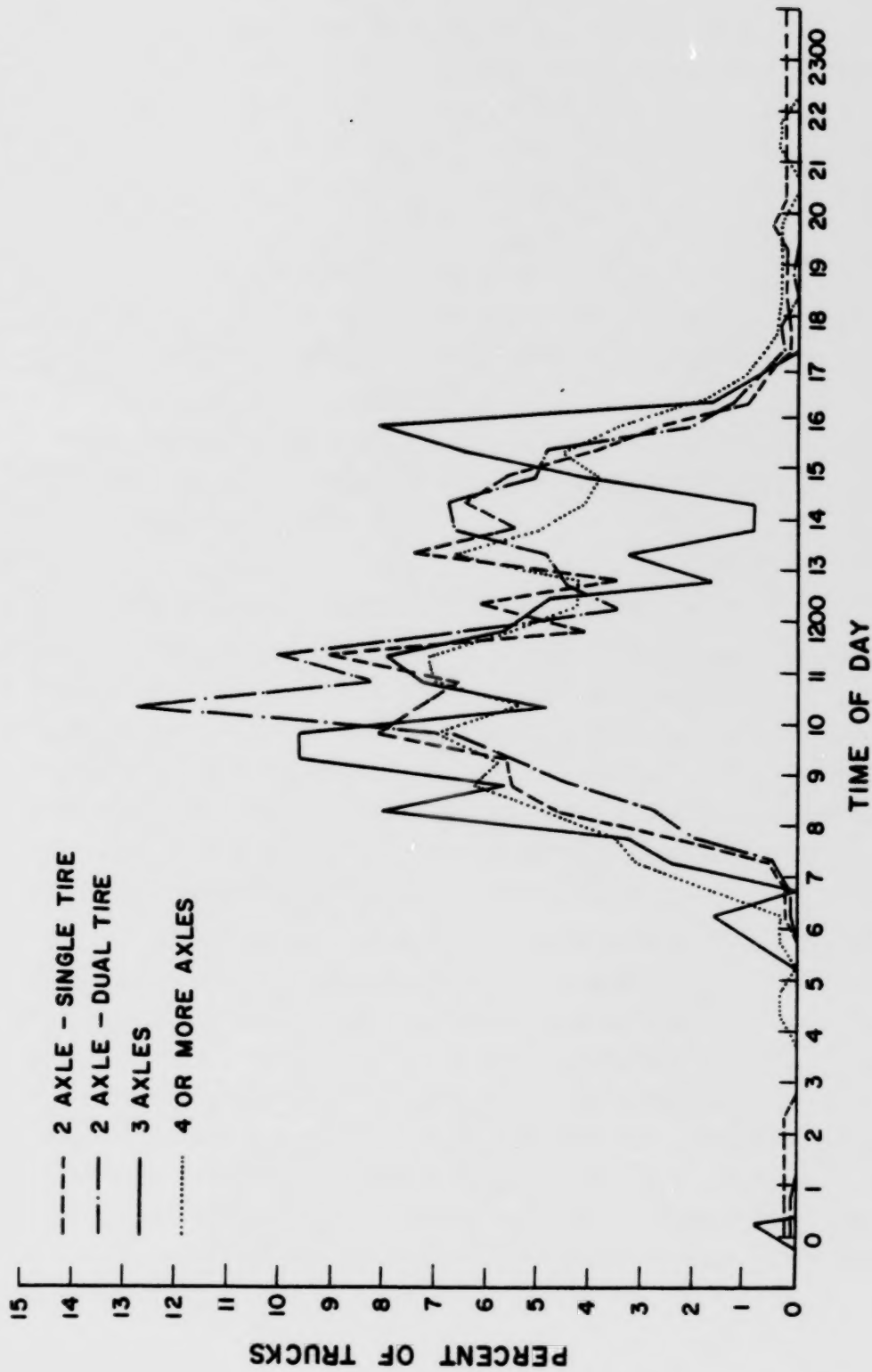
The daily truck volumes observed on the links of the Provincial highway network will depend on the characteristic modes of operation of the different trucking fleets. For example, many for-hire trucking companies assemble freight during the day and dispatch inter-city trucks late in the day. On the other hand many private trucking fleets operate primarily during normal working hours.

Figures 2.3 and 2.4 illustrate some characteristic truck movement profiles observed at a sample of manufacturing industries in the Metropolitan Toronto area in the early 1970s. Figure 2.3 illustrates that for finished products the movements of the multi-axle trucks (mainly inter-city) tended to be concentrated in the late afternoon hours, while the movements of the smaller trucks tended to be concentrated in the



Source: Hutchinson, B.G. (1974), "Principles of Urban Transport Systems Planning", McGraw-Hill Book Company

Figure 2.3 - 24 Hour Distribution of Truck Movements by Truck Type for Finished Product Deliveries



Source: Hutchinson, B.G. (1974), op. cit.

Figure 2.4 - 24 Hour Distribution of Truck Movements by Truck Type for Raw Material Deliveries

0700-0800 hr. period just prior to the peak commuting period. Figure 2.3 shows that a secondary peak in 2-axle trucks was observed in the 2200-2300 hr. period and this reflected the delivery activities of a daily newspaper plant. Figure 2.4 illustrates that the bulk of the raw materials deliveries by all truck types are concentrated in the mid-morning and mid-afternoon periods.

These characteristic modes of operation of inter-city trucks will vary over time as the congestion characteristics on the primary highway network change, particularly in the vicinity of large urban areas.

Figure 2.1 illustrates that truck movement patterns affect the level of service on different highway links. Level of service deficiencies and damage to pavements as a result of truck movements are of interest in this study.

2.5 Factors Influencing Truck Movement Patterns

The precise relationship between truck movement demands and the overall level of economic activity is not well understood, largely because of data limitations. Table 2.5 illustrates the evolution of freight modal shares at several times over the last two decades. It is important to note from this table that the trucking share of total revenues increased from 24.6 percent in 1960 to about 42 percent in the late 1970s, and the table indicates that the proportion has stabilized.

It has been noted previously in this report that the Transport Canada economic forecasting method for for-hire trucking is based on a very strong observed correlation between truck loadings and manufacturing output. Truck unloadings have a strong association with total output which is really a proxy for demand. This approach is supported by the analyses presented in the following chapters where truck movement patterns in Southern Ontario are shown to have a strong association with the inter-industry structure of the Province. This would suggest that longer term forecasts in trucking movement in the Province must recognize the struc-

TABLE 2.5 Freight Operating Revenue Shares, 1960-1978

	Rail %	Truck %	Marine %	Air %	Pipeline %
1960	56.1	24.6	13.7	0.6	5.0
1965	52.9	28.6	11.8	1.0	5.8
1970	40.4	42.2	9.9	1.7	5.8
1975	37.7	42.8	12.3	2.0	5.2
1978	41.0	41.8	10.4	2.1	4.7

Source: Strategic Planning (1981), "Canadian Freight Transportation System Performance and Issues", Transport Canada.

tural changes that are occurring in the Provincial economy. The decline of the traditional secondary industries, particularly those associated with the automobile industry, and their possible replacement by the electronics and communications industries, will have a strong influence on truck movement patterns, particularly along the freeway corridors to the west and southwest of the Metropolitan Toronto region.

Increasing energy costs may also have an important influence on trucking movements in the Province, with the expected increases during the 1980s leading to higher load factors. These increased energy costs may also lead to further growth in inter-modal services, particularly for the longer trip lengths.

CHAPTER 3

ALTERNATIVE APPROACHES TO LINK VOLUME ESTIMATION

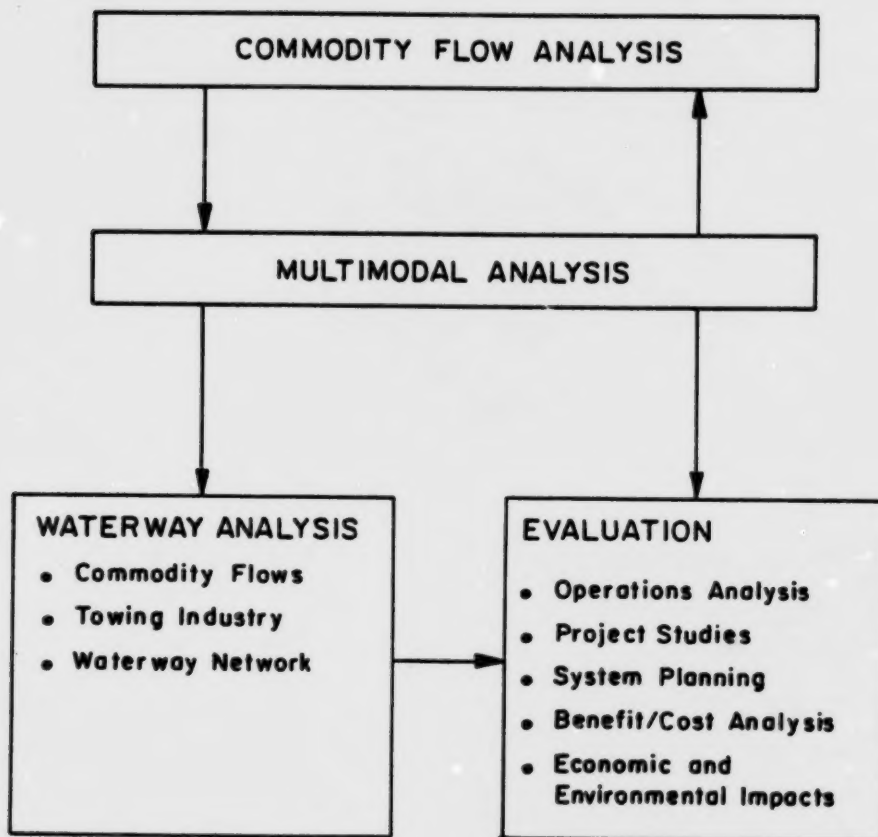
3.1 Introduction

A conceptual framework within which truck volumes on the Provincial highway system may be estimated has been outlined in Chapter 2. Ideally it would be desirable to link any truck movement model to a general model of the Provincial economy. The structure of the Provincial economy would yield commodity flow estimates with shipping decisions being simulated in order to derive truck movements. A general approach such as this would require a major commitment of time and resources. At the other extreme is the current approach whereby classification counts are used to establish the proportions of trucks in the vehicle flows on various parts of the Provincial highway network.

The purpose of this chapter is to explore alternative approaches to the problem of truck volume forecasting. Four general approaches are explored ranging from an economic-based approach through to an approach that focusses directly on traffic flows.

3.2 Economy-Commodity Flow Based Approach

Veith and Bronzini (1977) have described a very general approach developed to explain and predict goods movement demand for the U.S. inland waterway system. This modelling initiative was part of the U.S. Corps of Engineers Inland Navigation Systems Analysis (INSA). The broad structure of this approach is illustrated in Figure 3.1. Forecasts of demand for commodity transportation are provided by the commodity flow analysis model and the multi-modal analysis allocates these flows to the several modes on the basis of transport costs and performance criteria. The allocations to the inland waterway system are then used to estimate future towing industry fleet requirements and waterway network requirements. The diagram shows that there is a feedback from the multi-modal analysis to the commodity flow analysis, allowing transport costs and service levels to influence the spatial pattern, mix and quantities of commodity flows.



Source: Veith, M.T., and Bronzini, M.S. (1977), "Commodity Flow and Multimodal Transportation Analysis for Inland Waterway Planning", Transportation Research Board Annual Meeting, Washington, D.C.

Figure 3.1 - Broad Structure of the U.S. Corps of Engineers Inland Navigation Systems Analysis

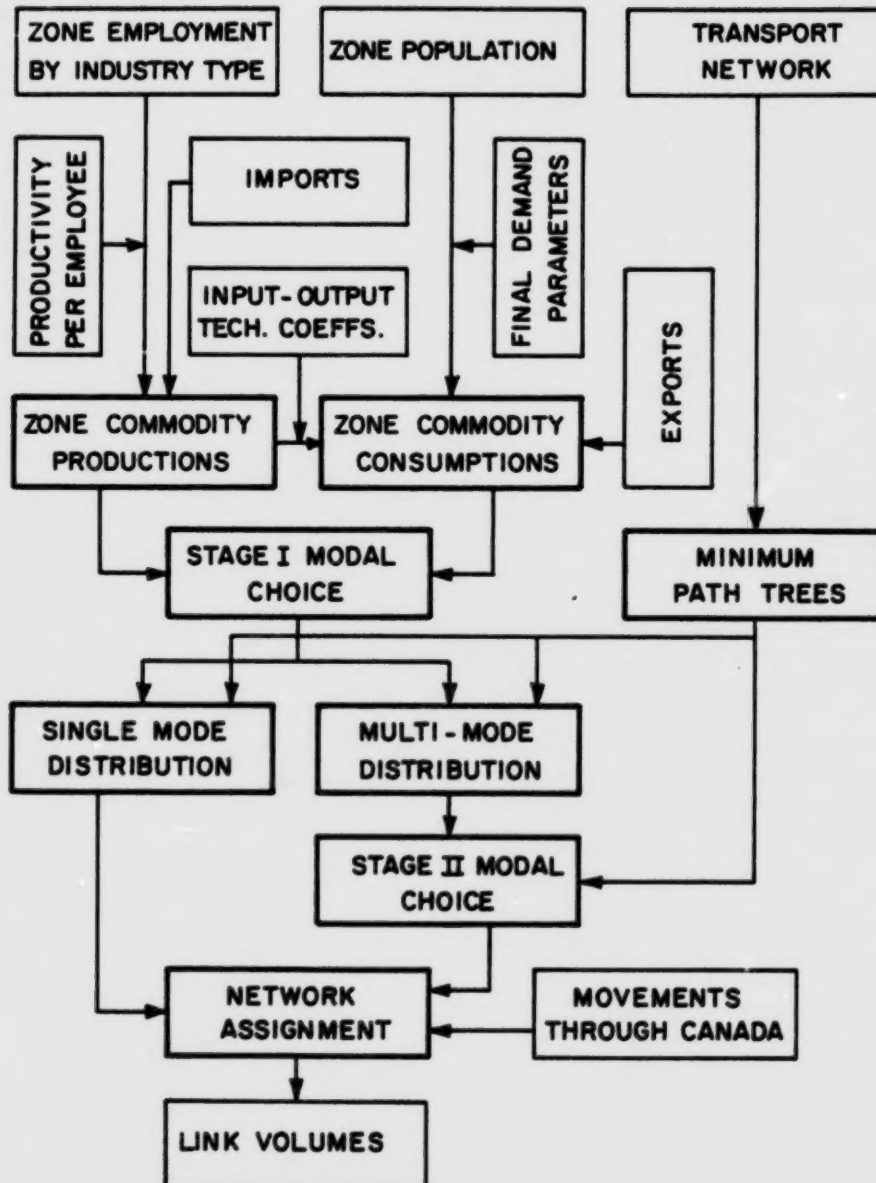
The commodity flow model is essentially a multi-region input-output table. The U.S. economy is divided into a set of regions with each region containing a set of economic sectors. Each economic sector produces an output to satisfy perceived demands and the particular resource inputs combined to produce these outputs depend on the delivered input prices, including transport prices, as each economic sector searches for optimum input combinations. Commodity flows occur as input raw materials travel to the economic sectors demanding them and as output products travel to locations of domestic consumer demand, export demand, and intermediate demands. The commodity flow model generates a demand for transportation which depends in part on transport price.

The multi-modal analysis is performed in a traditional transport systems analysis sense with the exception that modal share and network routing analysis are combined. Each commodity flow is described by origin region, destination region, commodity type and tonnage. Least cost routes from origin to destination are found for all shipments where costs are allowed to vary with shipment volume on each link. Costs are defined as the sum of the shipment cost, as determined by each network link cost function and the shipper-perceived cost of delay. The latter cost component is defined by the product of the transit time, commodity value, and commodity inventory value, where transit time relates to the link capacity functions.

Commodity shipments are assigned to the network using an iterative procedure which recognizes the delay function characteristics of each link in a fairly traditional capacitated assignment sense.

3.3 Adaptation of Traditional Multi-Stage Models

Hutchinson et al (1975) have described an attempt to develop a national commodity flow model for Canada which represents an adaptation of the multi-stage model structure used in urban transport planning studies. Figure 3.2 illustrates the broad structure of this model which consists of the eight modules outlined by the heavy lines in Figure 3.2 and these are: (i) the commodity production module, (ii) the commodity consumption module, (iii) the Stage I modal split module, (iv) the minimum path tree module,



Source: Hutchinson, B.G., et al (1975), "A National Commodity Flow Model", Canadian Journal of Civil Engineering, Vol. 2, No. 3.

Figure 3.2 - Structure of Commodity Flow Model

(v) the multi-mode commodity distribution module, (vi) the single mode commodity distribution module, (vii) the Stage II modal split module, and (viii) the network assignment module.

The principal inputs to each module are illustrated in Figure 3.2. The commodity productions and consumptions of each zone are estimated using the inter-industry information contained in the Canada input-output model and the household demand characteristics of each zone. The Stage I modal split module identifies those commodity productions and consumptions which are restricted to one mode of transport and for which commodity distribution patterns should be estimated separately from those commodities that may use any transport mode. The module also identifies any mode-specific linkages between particular production and consumption zones, particularly the natural resource movements, such as grain movements through Thunder Bay and iron ore movements to Hamilton.

Multi and single mode commodity distributions between production and consumption zones are estimated using a gravity model where the exponent of the deterrence function is calibrated for each commodity flow type. The Stage II modal split module estimates the split of demand between competing modes of transport using empirically determined probabilities of choice.

The estimated origin to destination flows by commodity type and mode are summed over all commodity types to obtain the total flows by mode. Exogenously estimated commodity flows between external zones which pass through Canada are added to the total flow matrices. The total flow matrices are then assigned to the corresponding modal transport networks using a minimum path, all-or-nothing procedure to produce link commodity flows in tons per annum.

3.4 Multi-Proportional Balancing Techniques

The success of the forecasting procedures described in the previous sections depends very heavily on the extent to which the spatial interaction linkages between commodity production and consumption centres, and the modal shipping decisions can be captured. An alternative approach is to focus more directly on the existing spatial interaction and modal

choice structures and to use this information to assist in estimating future truck flows.

The traditional approach in transport planning has been to calibrate some form of gravity model to an observed set of data, and to use this calibrated model to estimate future spatial interaction patterns. The approach described by Hutchinson et al (1975) is based on this method. There are significant difficulties with this approach because of the very real difficulty of attempting to capture the complexities of inter-industry commodity movements in terms of a very simple travel deterrence function. A great deal of evidence has been assembled over the past four or five years which demonstrates that the traditional spatial interaction models are relatively poor at capturing spatial interaction patterns for both commodity movements and person travel.

One of the original approaches to estimating spatial interaction patterns was the Fratar or growth factor approach. The essence of this approach is that the existing spatial interaction structure revealed by survey is used along with estimates of future trip ends to forecast future spatial interaction patterns. Recently, this and several other approaches to spatial interaction modelling have been recognized as special cases of the more general methodology known as log-linear contingency table analysis, Willekens (1981).

The two dimensional version of the log-linear model may be written in the following multiplicative or additive (log-linear) forms:

$$m_{ij} = w \cdot w_i^A \cdot w_j^B \cdot w_{ij}^{AB} \quad (3.1)$$

$$\ln m_{ij} = u + u_i^A + u_j^B + u_{ij}^{AB} \quad (3.2)$$

where m_{ij} = the flows between zones i and j ; w (or u) = the overall effect reflecting the total number of trips in the system and given by the geometric mean of the cell counts; w_i^A (or u_i^A) and w_j^B (or u_j^B) = the effects of the origin and destination zone sizes, respectively on the cell magnitudes, and w_{ij}^{AB} (or u_{ij}^{AB}) = the pure interaction effects between zones i and j .

Equation (3.1) may be recognized as a form of the gravity model where w_i is equivalent to the number of origins from zone i , w_j is equivalent to the number of destinations to zone j , w_{ij} is equivalent to the probability of a trip originating in zone i having a destination in zone j , and w is equivalent to the so-called balancing factor that ensures that the overall trip constraint is satisfied.

Table 3.1 summarizes the way in which the various effects that influence the cell flow magnitudes may be estimated for both the multiplicative and additive forms. The reader familiar with analysis of variance techniques will recognize the equivalence with these procedures. Perhaps the best way to illustrate the approach is by a simple numerical example, and this is provided in Figure 3.3.

The flow matrix is shown at the top of the diagram and indicates that there are a total of 900 trips in this 3 x 3 zone system. The decomposition of these flows into the various components identified in equations (3.1) and (3.2) are shown. The overall effect is calculated by using equations (2) and (10) of Table 3.1 where R and C represent the number of rows and columns, respectively. With the multiplicative form 81.063 represents the ninth root of the product. For the additive form, 4.395 represents one-ninth the sum of the natural logarithms of the flow entries. The row, column and inter-action effects isolated in Figure 3.3 have been determined by applying the relevant equations listed in Table 3.1.

The row and column effects simply reflect the relative sizes of each zone as an origin zone and as a destination zone, respectively. The interaction effects are the pure interaction effects that are independent of zone sizes. Any flow entry may be re-created by simply applying equation (1) or (9) to Table 3.1. For example:

$$\begin{aligned} m_{23} &= 81.063 \times 0.9234 \times 0.4483 \times 0.8940 \\ &= 30.0 \end{aligned}$$

or

$$\begin{aligned} \ln m_{23} &= 4.395 - 0.0790 - 0.8020 - 0.1128 \\ &= 3.40 \end{aligned}$$

TABLE 3.1 The Characteristics of the Log-Linear Model

Multiplicative Formulation		Additive Formulation	
$m_{ij} = v w_1^A w_j^B w_{ij}^{AB}$	(1)	$\ln m_{ij} = u + u_1^A + u_j^B + u_{ij}^{AB}$	(9)
Overall mean effect	$w = \left[\prod_{i,j} m_{ij} \right]^{\frac{1}{RC}}$	$u = \frac{1}{RC} \sum_{i,j} \ln m_{ij}$	(10)
Main effects	$w_1^A = \frac{1}{v} \left[\prod_j m_{1j} \right]^{\frac{1}{C}}$ w_j^B : analogous	$u_1^A = \frac{1}{C} \sum_j \ln m_{1j} - u$ u_j^B : analogous	(11)
First-order interaction effects (two-way or pairwise interaction)	$w_{ij}^{AB} = \frac{1}{z} \left[m_{ij} \right]$ with $z = v w_1^A w_j^B$	$u_{ij}^{AB} = \ln m_{ijk} - c$ with $c = u + u_1^A + u_j^B$	(12)
Constraints	$\prod_i w_1^A = \prod_j w_j^B$ $\prod_i w_{ij}^{AB} = \prod_j w_{ij}^{AB}$ $w = \exp u$ $w_1^A = \exp u_1^A$	$\sum_i u_1^A = \sum_j u_j^B$ $\sum_i u_{ij}^{AB} = \sum_j u_{ij}^{AB}$ $u = \ln v$ $u_1^A = \ln v_1^A$	(13) (14) (15)
	$w_{ij}^{AB} = \exp u_{ij}^{AB}$	$u_{ij}^{AB} = \ln v_{ij}^{AB}$	(16)

m_{ij} Flows

100	150	80	330
70	200	30	300
150	100	20	270
320	450	130	900

Multiplicative Form

Additive Form

overall effect

$$w = 81.063$$

$$u = 4.395$$

row effects

$$w_1^A = 1.3103$$

$$w_1^A = 0.2709$$

$$w_2^A = 0.9234$$

$$w_2^A = -0.0790$$

$$w_3^A = 0.8255$$

$$w_3^A = -0.1911$$

column effects

$$w_1^B = 1.2538$$

$$w_1^B = 0.2264$$

$$w_2^B = 1.7791$$

$$w_2^B = 0.5764$$

$$w_3^B = 0.4483$$

$$w_3^B = -0.8020$$

interaction effects

0.7509	0.7938	1.6801
0.7459	1.5018	0.8940
1.7878	0.8400	0.6667

-0.2871	-0.2317	0.5181
-0.2939	0.4059	-0.1128
0.5803	-0.1751	-0.4062

Figure 3.3 - A Simple Example of the Log-Linear Model

or

$$m_{23} = e^{3.40} = 30.0$$

An equivalent way of extracting the interaction effects from a set of flow data is to use a bi-proportional (or multi-proportional) balancing procedure. This is achieved by alternatively scaling the row and column entries so that each row and each column eventually sums to 1.0. Figure 3.4 shows a simple example using the same flow matrix as used in Figure 3.3. The cell entries illustrated in Figure 3.4 may be interpreted as the probabilities of interaction between a known origin zone and a particular destination zone, when all destinations have the same magnitudes. The entries in the final matrix of Figure 3.4 have the same interaction structure as those presented in Figure 3.3 and may be obtained from the interaction effects of the multiplicative model by dividing the cell entries by the row totals. This approach was used for the data analyses presented in subsequent chapters as a computer program was readily available.

The entries in the bi-proportionally balanced matrix may be re-adjusted to a new set of generations and attractions by reversing the procedure just described and Figure 3.5 shows a simple example. Generations in zone 3 are expected to increase from 270 to 400 trips and the attractions to zone 1 are expected to increase by 80 trips and to zone 2 by 50 trips. The example almost converges after three iterations.

The approach just described is valid if the structural change in the trucking market is minor. However, significant structural changes may be expected and these changes must be incorporated into the structural interaction matrix before it is adjusted to new marginal totals. For example, it seems clear that the motor vehicle industry in Ontario is undergoing decline and attempts are being made to stimulate the micro-electronics industry at selected locations throughout the Province. If these changes do occur, then there will be significant changes in the structure of the trucking market. A second structural change could occur if greater use is made of inter-modal facilities because of the continued increase in energy costs. Changes such as these are difficult to estimate with any

Original Flow Matrix

100	150	80	330
70	200	30	300
150	100	20	270
320	450	130	

First Iteration

.303	.455	.242	1.000
.238	.667	.100	1.000
.556	.370	.074	1.000
1.092	1.492	.416	

Second Iteration

.278	.305	.582	1.165
.213	.447	.240	0.900
.509	.248	.178	0.935
1.000	1.000	1.000	

Fifth Iteration

.231	.253	.516	1.000
.233	.487	.280	1.000
.538	.261	.201	1.000
1.002	1.001	.997	

Figure 3.4 - Bi-Proportional Balancing Procedure

Interaction Effects with New Generations and Attractions

0.231	0.253	0.516	330
0.233	0.487	0.280	300
0.536	0.260	0.204	400
400	500	130	1,030

First Iteration

76	184	170	330
70	146	84	300
214	104	82	400
360	334	336	1,030

Second Iteration

84	126	66	276
78	219	32	329
238	155	32	425
400	500	130	1,030

Third Iteration

101	151	78	330
71	200	29	300
224	146	30	400
396	497	130	1,030

Figure 3.5 - Bi-Proportional Adjustment of Interaction Effects to New Generations and Attractions

analytical technique. However, subjective estimates of these structural changes may be developed and incorporated in the spatial interaction matrix, with the revised matrix being adjusted to new marginals.

The approach just described assumes implicitly that the interaction structure will be the same between the base year in which the survey information was collected and the future year for which the forecasts are being developed. The gravity model, of course, adjusts expected generations and attractions to an interaction structure created by the travel deterrence function and the expected changes in travel times between zones. Expected changes in interaction effects that are based on subjective opinions may also be incorporated into this approach, and this may be the only way to reflect major structural changes expected over time.

3.5 Link Volume Based Approaches

The techniques described in the previous section may also be used to estimate origin-destination matrices from link volume data. Robillard (1975), Holm et al (1976), Willumsen (1978), Van Zuylen and Willumsen (1980), Hauer and Shin (1981) have also described methods of estimating origin-destination tables from observed link volumes. The various approaches differ in terms of the underlying assumptions about traffic behaviour and the complexity of the networks studies.

If the trip matrix is denoted by $\{T_{ij}\}$ and if no intra-zonal flows are admitted, $T_{ij} = 0$ for all $i = j$, and if p_{ij}^a denotes the proportion of trips between origin i and destination j using link a , then the flow V_a on link a will be given by:

$$V_a = \sum_i \sum_j p_{ij}^a T_{ij} \quad (3.3)$$

$$0 \leq p_{ij}^a \leq 1$$

The problem then is one of establishing the most probable $\{T_{ij}\}$ matrix that satisfies equation (3.3).

The method is dependent upon the method of assignment which determines p_{ij}^a . For the Provincial highway network the all-or-nothing assignment principle is adequate which may be stated as:

$$p_{ij}^a = \begin{cases} 0 & \text{if link } a \text{ is not used by trips from } i \text{ to } j \\ 1 & \text{if link } a \text{ is used.} \end{cases}$$

The problem is a multi-proportional adjustment problem of the general type described in the previous section, although a little more complex to implement depending on the number of zones and individual links in the system. An initial estimate of the origin-destination matrix, say $\{t_{ij}\}$ is adjusted in a multi-proportional way until the modelled flows on each link are close to the observed link flows V_a . The critical element of the approach is the nature of the initial starting matrix whose entries could be established from a survey, or some hypothesis about spatial interaction between the various zones.

This approach could be used to estimate the most likely origin-destination matrix for total truck trip flows in Ontario if detailed link truck count data were available. The interaction information obtained from the MTC 1978 Commercial Vehicle Survey could be used as the initial matrix. More stratified matrices (say by different commodity groups) would require some form of roadside interview in order to establish an appropriate decomposition of the link flow data.

3.6 Evaluation of Alternative Techniques

The four approaches described in the previous sections cover a very wide range of techniques in terms of complexity, data requirements, costs and times of development and sensitivity to policy issues. Clearly, each technique has advantages and disadvantages and Table 3.2 attempts to summarize these for each of the four techniques.

Each of the four techniques has been ranked with respect to six criteria in a very subjective way. Clearly the input-output/commodity flow approach has the best theoretical foundations since the methodology recognizes explicitly that the trucking function is a direct consequence of the economic mechanisms operating in a particular region. The adaptation

TABLE 3.2 Ranking of Alternative Forecasting Methods

	Forecasting Method			
	Commodity Flow	Multi-Stage Aggregate	Balancing Techniques	Link Flow Expansions
Scientific Integrity	1	2	3	4
Data Requirements				
- Calibration	4	3	2	1
- Forecasting	4	3	2	1
Analysis Utility *				
- Economic	1	2	3	4
- Traffic	4	2	1	3
Time to Develop	4	3	2	1
Development Costs	4	3	2	1
Sensitivity to Structural Changes	1	2	3	4

* Refers to the potential utility of each approach for the analysis of economic policies and for traffic forecasting.

Note: the ratings 1 (best) through 4 (worst) denote the relative capabilities of each forecasting method with respect to the criteria listed; numbers must only be interpreted in the ordinal sense.

of the multi-stage aggregate models represents an attempt to move the traditional travel demand models into a more general economic framework. However, it is very clear that the use of a gravity model to attempt to synthesize the spatial structure of commodity flows is a major weakness. The other two techniques are based implicitly on the assumption that the existing spatial interaction structure will continue into the future. These techniques also require exogenous estimates of the truck trips demands likely to be generated by each community.

Table 3.2 suggests that the data requirements, both for calibration and forecasting, are directly related to the scientific integrity of the models because of their complexity. While the commodity flow and multi-stage aggregate approaches might have the greatest utility for economic policy analysis the time and costs required to develop these methods adequately would be very high.

The rankings presented in Table 3.2 suggest that the two techniques that focus directly on truck traffic movements are more appropriate to the Ministry's objectives at this time. While the methods are unable to reflect major structural changes in the Ontario trucking market they are quite appropriate for short-run forecasts. They have modest data requirements and the necessary computer techniques are either available or can be quickly developed.

It has been pointed out in the previous sections that the origin-destination matrix balancing methods and the methods that use link flow data are analytically equivalent. While the link flow-based approach is capable of producing an aggregate origin-destination matrix, matrices stratified in terms of the major commodity groups cannot be produced. It is felt that the approach which relies on a sample of origin to destination movements is more appropriate than a link volume based approach. A more precise matrix may be estimated and the stratification of the trucking market by commodity group provides an opportunity for incorporating expected structural changes in the Ontario economy. This approach is developed in more detail in Chapter 8 following the analyses of the existing information on truck movements in Ontario.

CHAPTER 4

STATISTICS CANADA SURVEY : TRIP GENERATION ANALYSES

4.1 The For-Hire Trucking Survey

Statistics Canada has conducted a survey of for-hire trucking in Canada each year since 1973. The universe of this survey consists of for-hire carriers earning more than \$100,000 per year from the domestic movements of goods over more than 15 miles (24.1 km) on public roads.

The for-hire trucking survey is a two-stage, twice replicated proportional to size systematic sample of 225,000 shipments by for-hire carriers within Canada. Stratifications of the sampling universe are constructed according to the area of province of operation, type of trucking activity, and size of carrier or terminal measured in terms of revenues.

The first stage of the sampling identifies the carriers to be surveyed and the second stage obtains groups of 100 shipments from the files of each carrier. The entire sampling procedure is repeated twice in order to obtain two independent sets of samples. Individual shipment data are expanded to estimate the total activities of each carrier. The relative size of the carrier to the structure size is used to expand the carrier estimate to the stratum level. The average of the stratum estimates provides a combined stratum estimate, and the average of the replicate estimates is used as the final estimate of the stratum. The coefficient of variation is estimated from the two independent samples. Appendix A provides a more detailed description of the sampling procedure along with comments on its statistical reliability.

The data obtained in this survey are published for the major population centres of Canada in terms of estimated revenues, estimated tonnes and estimated tonne-kilometres. Estimates of commodity movements between each pair of population centres are also available, as well as movements stratified by major commodity group. Appendix A contains the information obtained in the 1979 survey for the ten Ontario population centres and Montreal.

4.2 Commodity Generations and Attractions : 1973-1979

Table 4.1 summarizes the estimates of for-hire trucking tonnes attracted to each of the ten Ontario population centres and Montreal between 1973 and 1979. This table shows that there have been substantial year to year variations in the total commodity attraction levels. For example, the total attractions increased by about 26 percent from 1973 to 1979. Most of this change was due to the increase in the tonnes attracted to Toronto.

Tables 4.2 summarizes the estimates of for-hire trucking tonnes generated by each of the ten Ontario population centres and Montreal. A similar increase in the total commodity generations between 1978 and 1979 may also be noted along with a similar increase in the generations for the Toronto region.

A more detailed evaluation of the individual entries in these tables would suggest some substantial sampling errors. For example, between 1974 and 1975 commodity attractions to Thunder Bay increased by 522 percent; between 1977 and 1978 attractions to the Kitchener region increased by 135 percent. While some of these abrupt year to year changes may be explained by the survey sampling error, the case of Thunder Bay raises an issue about the reliability of the survey, at least for the smaller population centres.

4.3 Availability of Independent Variables

The development of prediction equations relating commodity attractions and productions for each of the population centres to an appropriate independent variable is severely constrained by the small number of independent observations (ten) in each year of the survey. The number of independent variables available to characterize the level of economic activity in each of the ten population centres is also limited. The principal variables available are:

1. population
2. total trucks registered
3. manufacturing man-hours by sector

TABLE 4.1 For-Hire Trucking Commodity Tonnes Attracted

	1973	1974	1975	1976	1977	1978	1979
Ottawa-Hull	1,686,000	1,354,000	1,300,000	1,560,000	1,871,000	1,724,000	1,611,000
Oshawa	882,000	882,000	882,000	882,000	974,000	1,305,000	1,689,000
Toronto	11,739,000	9,309,000	13,409,000	15,661,000	15,100,000	13,001,000	21,156,000
Hamilton	3,382,000	4,119,000	3,901,000	3,380,000	2,662,000	3,473,000	3,989,000
St.Cath. - N.F.	1,454,000	1,222,000	1,744,000	1,838,000	1,997,000	2,134,000	2,590,000
Kitchener	1,712,000	1,115,000	913,000	1,348,000	806,000	1,892,000	1,789,000
London	1,353,000	1,284,000	1,881,000	1,126,000	934,000	1,171,000	1,163,000
Windsor	2,560,000	2,334,000	1,870,000	1,755,000	1,598,000	1,338,000	1,405,000
Sudbury	1,284,000	312,000	703,000	508,000	482,000	497,000	419,000
Thunder Bay	296,000	217,000	1,349,000	240,000	266,000	227,000	268,000
Montreal	7,620,000	8,425,000	10,115,000	6,844,000	5,716,000	7,790,000	7,517,000
TOTALS	33,968,000	30,573,000	38,067,000	35,142,000	32,406,000	34,552,000	43,596,000

TABLE 4.2 For-Hire Trucking Commodity Tonnes Generated

	1973	1974	1975	1976	1977	1978	1979
Ottawa-Hull	576,000	644,000	1,279,000	962,000	1,108,000	808,000	956,000
Oshawa	753,000	753,000	753,000	753,000	666,000	571,000	716,000
Toronto	9,455,000	8,207,000	12,653,000	12,743,000	13,276,000	12,250,000	18,728,000
Hamilton	4,115,000	3,872,000	4,028,000	6,048,000	5,168,000	5,518,000	6,487,000
St.Cath. - N.F.	1,648,000	1,600,000	1,152,000	1,315,000	1,297,000	1,742,000	1,702,000
Kitchener	620,000	688,000	609,000	877,000	559,000	854,000	1,322,000
London	731,000	1,560,000	1,485,000	733,000	847,000	878,000	1,223,000
Windsor	1,234,000	1,013,000	727,000	913,000	681,000	1,105,000	1,126,000
Sudbury	1,131,000	210,000	325,000	1,236,000	345,000	435,000	239,000
Thunder Bay	281,000	297,000	281,000	488,000	279,000	428,000	407,000
Montreal	11,645,000	11,904,000	8,957,000	10,049,000	9,162,000	9,802,000	8,147,000
TOTALS	32,189,000	30,748,000	32,249,000	36,117,000	33,388,000	34,391,000	41,053,000

4.3.1 Inter-Relationships Between Variables

One of the difficulties of developing regression equations at this coarse spatial scale of only ten zones is that the three independent variables are likely to be strongly inter-related. Figure 4.1 illustrates the relationship between truck registration and population, while Figures 4.2 and 4.3 illustrate relationships between total manufacturing man-hours and population for 1977 and 1978, respectively. The diagrams illustrate that each pair of variables are strongly correlated with deviations from the trend lines reflecting some region-specific differences, such as Ottawa with its lower than average manufacturing base.

There are substantial difficulties in using any of these variables for both analysis and forecasting. For example, trucks are registered to the corporate address but may be stationed at other locations. A second difficulty is that truck trip rates established with respect to any one of these variables may not be stable over time. Greater productivity from the trucking fleet and the changing role of labour in the manufacturing industries are examples of potential instabilities. When more sophisticated information becomes available it may be possible to develop generation and attraction equations in terms of more direct measures of economic output and consumption.

4.4 Commodity Attraction Equations

Separate regression equations have been developed in terms of each of the three independent variables identified previously and these are:

$$\begin{aligned} & \text{1978 Annual Commodity Attractions by For-Hire Trucks} \\ & = 311,799 + 0.025 \text{ (1978 Manufacturing Man-Hours)} \end{aligned} \quad (4.1)$$

$$r^2 = 0.99 \quad t = 25.3 \quad s_e = 4.40 \times 10^5 \text{ tonnes}$$

$$\begin{aligned} & \text{1979 Annual Commodity Attractions by For-Hire Trucks} \\ & = 90,650 + 9.20 \text{ (MTC Truck Registration)} \end{aligned} \quad (4.2)$$

$$r^2 = 0.54 \quad t = 3.0 \quad s_e = 8.80 \times 10^5 \text{ tonnes}$$

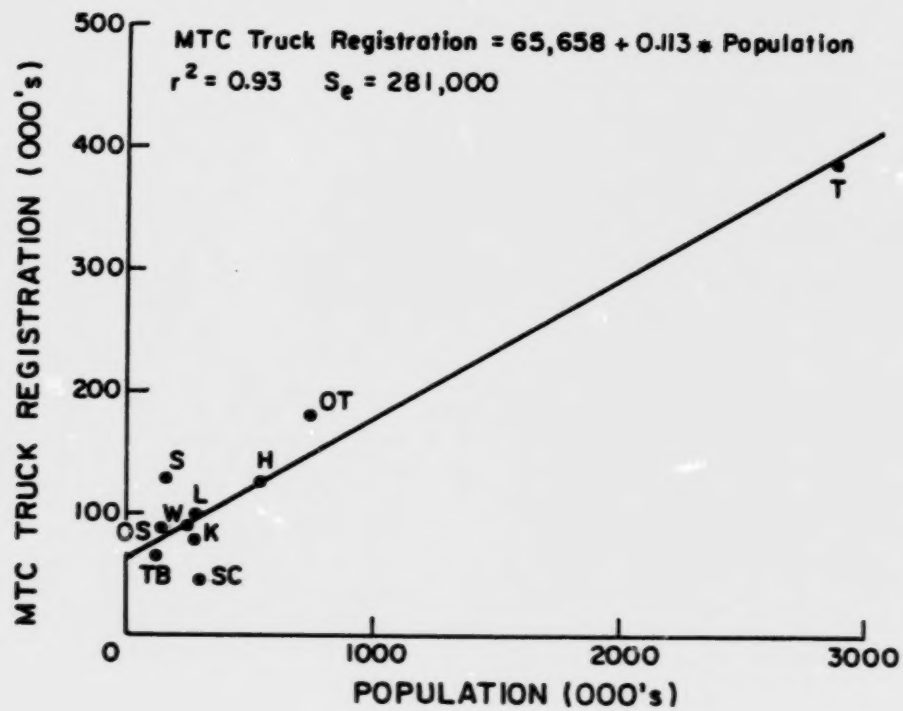


Figure 4.1 - MTC Truck Registration 1980 vs Population 1979

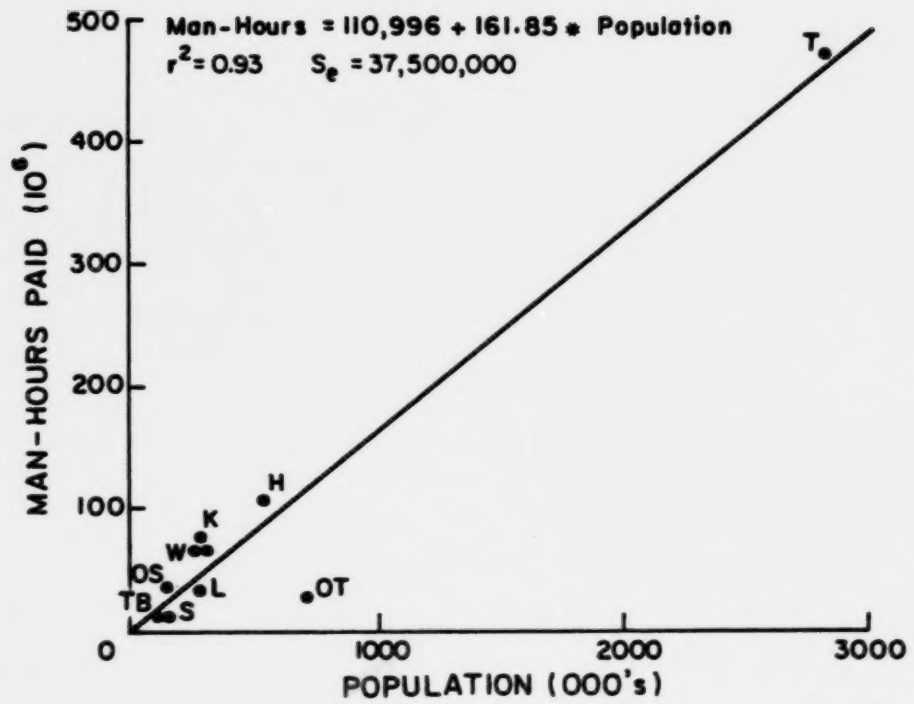


Figure 4.2 - Manufacturing Man-Hours Paid vs Population, 1977

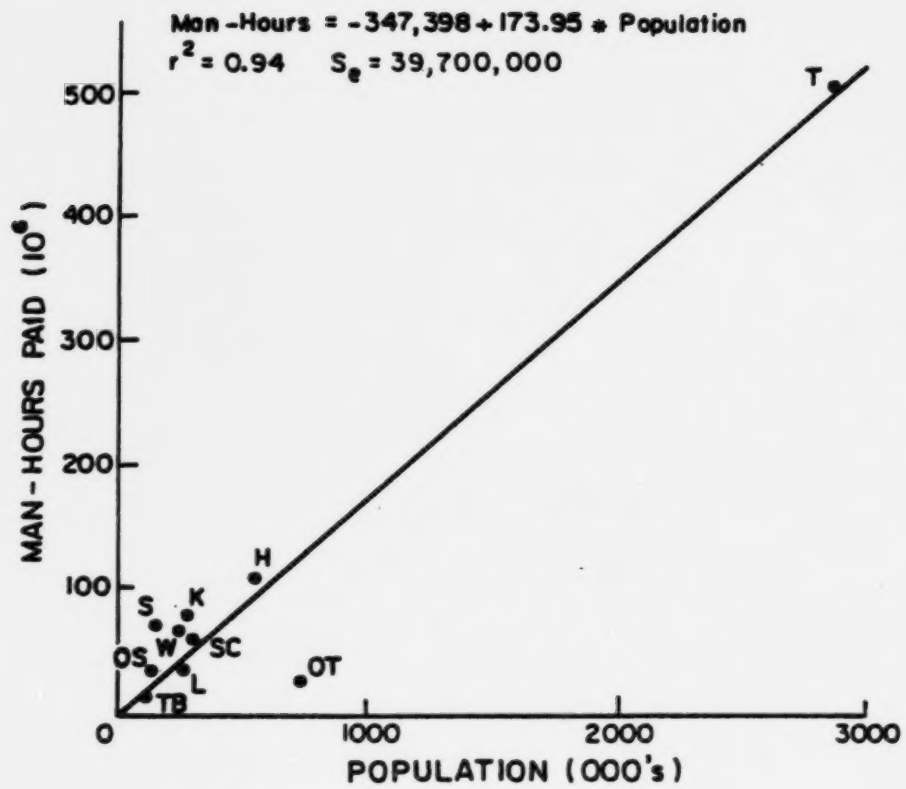


Figure 4.3 - Manufacturing Man-Hours Paid vs Population, 1978

$$\begin{aligned} & \text{1979 Annual Commodity Attractions by For-Hire Trucks} \\ & = 572,636 + 1.25 (\text{Population}) \quad (4.3) \\ & r^2 = 0.73 \quad t = 4.6 \quad s_e = 6.76 \times 10^5 \text{ tonnes} \end{aligned}$$

The use of 1978 commodity attractions in equation (4.1) was necessary because 1979 manufacturing man-hours data were not available from Statistics Canada.

A comparison of the three equations shows that equation (4.1) has the highest explanatory power. While the regression coefficient is significant at the 1 percent level equation (4.1) has a high standard error. The largest under-estimation residuals were associated with Ottawa, Hamilton and St. Catharines-Niagara Falls, while the largest over-estimation residuals were associated with Kitchener, Windsor and Thunder Bay. The under-estimation of Ottawa is clearly related to its atypical economic base which contains little manufacturing employment. The under-estimation of Hamilton is probably related to its concentration of heavy manufacturing industries. The economic bases of Kitchener and Windsor are dominated by manufacturing industries which result in the over-estimation of commodity attractions to these areas.

Appendix B summarizes the manufacturing man-hours data available from Statistics Canada and illustrates that manufacturing man-hours are stratified into a number of industry sectors. A variety of regression equations were estimated and evaluated in an attempt to improve on the statistical quality of equation (4.1). The small number of independent observations (ten) constrained the number of valid alternatives and the use of total manufacturing man-hours as the independent variable was found to be the most appropriate equation form. Appendix C provides a more detailed analysis of the commodity attraction and generation rates in terms of manufacturing man-hours.

4.5 Commodity Generation Equations

The three commodity generation equations developed from the Statistics Canada for-hire trucking data are:

1978 Annual Commodity Generations by For-Hire Truck

$$= 158,233 + 0.024 (1978 \text{ Manufacturing Man-Hours}) \quad (4.4)$$

$$r^2 = 0.93 \quad t = 9.9 \quad s_e = 1.1 \times 10^6 \text{ tonnes}$$

1979 Annual Commodity Generations by For-Hire Truck

$$= - 399,285 + 12.980 (\text{MTC Truck Registration}) \quad (4.5)$$

$$r^2 = 0.61 \quad t = 3.5 \quad s_e = 1.20 \times 10^6 \text{ tonnes}$$

1979 Annual Commodity Generations by For-Hire Truck

$$= 320,663 + 1.699 (\text{Population}) \quad (4.6)$$

$$r^2 = 0.61 \quad t = 3.4 \quad s_e = 1.20 \times 10^6 \text{ tonnes}$$

Equation (4.4) has the best statistical qualities in terms of the three statistical criteria shown. The standard error is very large with the largest under-estimation residuals being associated with Hamilton and Sudbury and the largest over-estimation residuals being associated with Oshawa, Kitchener and Windsor.

If the for-hire trucking data could be coded to a finer spatial system without significant losses in statistical reliability, then improved prediction equations with a richer array of independent variables might be developed. With the present system of ten major population centres only broad statistical associations between aggregate sets of variables can be developed.

CHAPTER 5

STATISTICS CANADA SURVEY : SPATIAL INTERACTION ANALYSES

5.1 Origin-Destination Tables

Origin-destination tables of commodity movements by for-hire trucks have been obtained for the 1979 survey. The data available are for estimated total shipments as well as for six commodity groups. These origin-destination tables are presented in Appendix A. Only three of these tables are analyzed in this chapter and these are for total shipments, Group 4 (machinery, transport equipment, electrical products) and Group 5 (primary metal and metal fabrications) shipments. While origin-destination tables exist in Appendix A for the other four major commodity groups they have not been analyzed since many of the cell entries have been aggregated for confidentiality or statistical reliability reasons.

Table 5.1 summarizes the information for total tonnes of commodities shipped by for-hire trucks between the eleven population centres that have the major impact on Ontario truck movements. For the system identified in Table 5.1 the total estimated shipments exceeded 24 million tonnes. It should be noted that the Montreal entries represent only those transactions between the ten Ontario population centres and Montreal.

Tables 5.2 and 5.3 summarize the transaction matrices for the two principal commodity groups carried by for-hire trucking. Commodity Group 4 movements account for 40 percent of the total movements, while commodity Group 5 movements account for about 15 percent.

5.2 Bi-Proportional Matrices

The transaction matrices presented in Tables 5.1, 5.2 and 5.3 have been manipulated using a bi-proportional balancing procedure. Bi-proportional balancing scales the rows and columns alternatively until the sum of the entries in each row and each column sum to a constant

TABLE 5.1 Total Estimated For-Hire Trucking Flows (tonnes), Statistics Canada 1979

	Ottawa-Hull	Oshawa	Toronto	Hamilton	St. Cath.-N.Y.	Kitchener	London	Windsor	Sudbury	Thunder Bay	Montreal	Total
Ottawa-Hull	36,101	189	120,421	9,369	3,040	8,615	1,819	17,190	7,151	132	271,134	475,161
Oshawa	29,975		189,162	70,094	53,851	53,943	3,671	20,821	1,626	51	108,649	531,843
Toronto	390,607	437,377	7,650,912	1,621,157	665,535	905,929	414,365	357,205	189,481	95,200	875,314	13,603,082
Hamilton	25,556	155,177	2,535,247	21,065	848,511	306,067	76,403	197,051	29,717	14,146	319,989	4,528,929
St. Cath.-N.Y.	6,052	217,316	460,972	250,866	147,003	29,126	38,516	45,713	8,358	612	76,342	1,280,876
Kitchener	17,795	199,562	407,999	176,765	19,195	27,428	39,867	37,542	6,877	594	46,912	980,536
London	7,749	718	118,017	39,728	30,942	54,314	18,105	22,982	1,035	526	33,017	327,133
Windsor	33,577	65,691	267,306	65,209	114,850	24,066	41,835	65,306	2,081	2,328	55,650	737,899
Sudbury	1,602		57,392	1,902	4,738	13	126	1,132	3,344	768	4,699	75,716
Thunder Bay	13	331	28,915	11,535		9,367	5,918	562	3,479		17,797	77,917
Montreal	488,548	19,054	664,016	110,681	41,311	41,893	44,804	27,211	23,325	10,370	522,188	1,993,401
Total	1,037,575	1,095,415	12,500,359	2,378,371	1,928,976	1,460,761	685,429	792,715	276,474	124,727	2,331,691	24,612,493

TABLE 5.2 Commodity Group 4 Flows (tonnes), Statistics Canada 1979
(machinery, transport equipment, electrical products)

	Ottawa-Hull	Oshawa	Toronto	Hamilton	St. Cath.-N. P.	Kitchener	London	Windsor	Sudbury	Thunder Bay	Montreal	Total
Ottawa-Hull	23,528		70,232	6,802	1,865		912	14,466	4,818		198,514	321,137
Oshawa	620		33,345	45,667	21,797	32		744			37,614	139,819
Toronto	124,040	132,459	2,604,309	706,216	282,938	423,702	101,765	82,450	63,852	60,369	241,261	4,823,361
Hamilton	1,781	133,955	1,677,666		759,499	211,473	58,902	171,696	21,140	6,607	273,945	3,316,664
St. Cath.-N. P.	1,044	27,579	214,774	150,334	55,503	14,999	19,527	22,084	7,631	523	39,852	553,850
Kitchener	4,162	704	148,201	89,406	8,757		7,504	11,198	32	344	19,897	290,205
London	4,094	22	22,110	512	10,815	3,923		5,520	3		1,569	48,568
Windsor	712	15,660	34,525	13,706	45,520	2,137	193	50,623			556	163,632
Sudbury	1,487		37,172	1,725	4,738			1,132	1,413	347	4,375	52,389
Thunder Bay		331	25,923	11,535		9,347	838	562	3,448		17,710	69,694
Montreal	203,222	10,150	220,866	76,369	33,853	15,218	11,578	20,021	6,367	8,184	231,825	837,653
Total	364,690	320,860	5,089,123	1,102,272	1,225,285	680,831	201,219	380,496	108,704	76,374	1,067,118	10,616,972

TABLE 5.3 Commodity Group 5 Flows (tonnes), Statistics Canada, 1979
(primary metal, metal fabricating)

	Ottawa-Hull	Oshawa	Toronto	Hamilton	St. Cath.-N.Y.	Kitchener	London	Windsor	Sudbury	Thunder Bay	Montreal	Total
Ottawa-Hull	340	159	35,899	713	60	8,596	432	2,724	268	132	38,698	88,021
Oshawa	25,083		125,717	21,150	15,924	18,667	3,568	20,077	1,586	51	71,000	302,823
Toronto	107,259	87,705	274,760	145,195	226,366	224,537	83,918	95,330	22,635	9,644	299,303	1,576,632
Hamilton	10,588	13,864	140,142		26,343	56,675	9,395	13,886	4,940	2,478	33,793	312,104
St. Cath.-N.Y.	1,892	189,438	97,896	26,717	22,230	4,845	721	19,993	483	89	21,793	386,097
Kitchener	1,846	196,936	106,349	7,054	7,921		16,793	7,163	2,264	250	22,146	368,722
London	411	664	18,967	28,431	2,683	35,038	1,979	3,853	922	54	15,758	108,760
Windsor	20,836	19,711	139,364	24,893	12,263	13,468	17,901	5,702	2,081	2,328	33,876	292,423
Sudbury	78		6,925	177		13	126		1,916	421	195	9,851
Thunder Bay			2,705			20	1,024		31		77	3,857
Montreal	167,269	4,980	170,008	18,560	3,589	4,224	9,619	6,698	11,782	2,050	184,103	582,882
Total	335,602	513,457	1,118,712	272,890	317,379	366,083	145,476	175,426	48,908	17,497	720,742	4,032,172

magnitude, say 1. The effect of this operation is to produce matrices in which the entries represent the interaction magnitudes that would occur between zones of equal size, or the pure interaction effects. This concept has been discussed in Chapter 3 in more detail.

The bi-proportionally balanced equivalent of the matrices presented in Tables 5.1, 5.2 and 5.3 are given in Tables 5.4, 5.5 and 5.6, respectively. Tables 5.4 shows the interaction probabilities between each pair of the eleven population centres, including the intra-zonal interactions for shipments over distances greater than 25 km. The table illustrates that the strongest generation-attraction interaction probabilities exist between Ottawa-Hull and Montreal, Kitchener and Oshawa, Hamilton and Toronto, Hamilton and St. Catharines-Niagara Falls, Sudbury and Thunder Bay, and Thunder Bay and Sudbury.

Inspection of Tables 5.5 and 5.6 suggest that the interaction structure is not the same for each commodity group. The strongest interactions for Group 4 commodities are between Ottawa-Hull and Montreal, Toronto and Thunder Bay, Windsor and Oshawa, and Thunder Bay and Sudbury.

5.3 Cluster Analysis

A useful technique for attempting to isolate the similarities in the shipping destination patterns of the ten population centres of Ontario is cluster analysis. The clustering method used in this investigation is Ward's method, Hutchinson and Smith (1979). This technique begins with ten population centres and groups them into a series of clusters on the basis of similarities in their destination probability vectors. The aggregation is continued until all of the census tracts are grouped into one cluster.

The clustering technique uses a measure of Euclidean distance between the destination-zone probabilities of two census tracts where this distance is defined in the following way:

$$d_{ij} = \left[\sum_{k=1}^n \frac{(p_{ik} - p_{jk})^2}{n} \right]^{1/2} \quad (5.1)$$

TABLE 5.4 Interaction Probabilities, Total Tonnes

	Ottawa-Hull	Oshawa	Toronto	Hamilton	St. Cath.-N.P.	Kitchener	London	Windsor	Sudbury	Thunder Bay	Montreal	Total
Ottawa-Hull	0.1937	0.0010	0.0706	0.0245	0.0103	0.0369	0.0158	0.1137	0.1241	0.0118	0.3952	0.9996
Oshawa	0.1306		0.0900	0.1488	0.1481	0.1875	0.0258	0.1138	0.0229	0.0037	0.1286	0.9998
Toronto	0.0545	0.0616	0.1167	0.1103	0.0587	0.1009	0.0935	0.0626	0.0856	0.2224	0.0332	1.0000
Hamilton	0.0125	0.0767	0.1358	0.0050	0.2627	0.1197	0.0606	0.1212	0.0471	0.1161	0.0426	1.0000
St. Cath.-N.P.	0.0086	0.3170	0.0729	0.1769	0.1343	0.0336	0.0901	0.0829	0.0391	0.0148	0.0300	1.0004
Kitchener	0.0330	0.3727	0.0826	0.1595	0.0224	0.0405	0.1193	0.0872	0.0412	0.0184	0.0236	1.0004
London	0.0424	0.0040	0.0705	0.1059	0.1069	0.2371	0.1601	0.1577	0.0183	0.0481	0.0491	1.0001
Windsor	0.0726	0.1431	0.0631	0.0687	0.1567	0.0415	0.1461	0.1770	0.0145	0.0842	0.0327	1.0002
Sudbury	0.0417		0.1634	0.0242	0.0780	0.0003	0.0053	0.0370	0.2819	0.3348	0.0333	0.9999
Thunder Bay	0.0003	0.0078	0.0735	0.1309		0.1740	0.2226	0.0164	0.2619		0.1126	1.0000
Montreal	0.4100	0.0161	0.0609	0.0453	0.0219	0.0281	0.0608	0.0286	0.0633	0.1456	0.1191	0.9997
Total	1.0001	1.0000	1.0000	1.0000	1.0000	1.0001	1.0000	1.0001	0.9999	0.9999	1.0000	

TABLE 5.5 Interaction Probabilities, Commodity Group 4

	Ottawa-Hull	Oshawa	Toronto	Hamilton	St. Cath.-N.Y.	Kitchener	London	Windsor	Sudbury	Thunder Bay	Montreal	Total
Ottawa-Hull	0.2278				0.0062		0.0324	0.1002	0.1636		0.3881	0.9995
Oshawa	0.0200		0.1021	0.3717	0.2424	0.0012		0.0172			0.2449	0.9995
Toronto	0.0392	0.1015	0.0781	0.0563	0.0308	0.1614	0.1177	0.0186	0.0707	0.3105	0.0154	1.0002
Hamilton	0.0011	0.2059	0.1010		0.1659	0.1616	0.1367	0.0778	0.0470	0.0682	0.0350	1.0002
St. Cath.-N.Y.	0.0035	0.2275	0.0694	0.1290	0.0651	0.0615	0.2432	0.0537	0.0910	0.0290	0.0274	1.0003
Kitchener	0.0458	0.0188	0.1551	0.2486	0.0333		0.3029	0.0882	0.0012	0.0617	0.0442	0.9998
London	0.2142	0.0028	0.1099	0.0068	0.1952	0.2476		0.2055	0.0006		0.0166	1.0002
Windsor	0.0071	0.3774	0.0326	0.0344	0.1559	0.0256	0.0070	0.3595			0.0011	1.0006
Sudbury	0.0767		0.1822	0.0225	0.0843			0.0417	0.2555	0.2915	0.0456	1.0000
Thunder Bay		0.0219	0.0673	0.0796		0.3081	0.0839	0.0110	0.3304		0.0977	0.9999
Montreal	0.3646	0.0442	0.0377	0.0346	0.0209	0.0329	0.0761	0.0257	0.0401	0.2392	0.0840	1.0000
Total	1.0000	1.0000	1.0000	1.0001	1.0000	0.9999	0.9999	1.0001	1.0001	1.0001	1.0000	

TABLE 5.6 Interaction Probabilities, Commodity Group 5

	Ottawa-Hull	Oshawa	Toronto	Hamilton	St. Cath.-N.Y.	Kitchener	London	Windsor	Sudbury	Thunder Bay	Montreal	Total
Ottawa-Hull	0.0123	0.0021	0.1439	0.0225	0.0029	0.1943	0.0118	0.1469	0.0286	0.0546	0.3802	1.0001
Oshawa	0.1703		0.0946	0.1253	0.1425	0.0792	0.0183	0.2032	0.0318	0.0040	0.1309	1.0001
Toronto	0.0895	0.0261	0.0254	0.1058	0.2490	0.1171	0.0528	0.1186	0.0558	0.0921	0.0678	1.0000
Hamilton	0.0585	0.0273	0.0858		0.1918	0.1956	0.0391	0.1144	0.0806	0.1565	0.0507	1.0003
St. Cath.-N.Y.	0.0108	0.3865	0.0621	0.1335	0.1677	0.0173	0.0031	0.1706	0.0082	0.0058	0.0339	0.9995
Kitchener	0.0132	0.5035	0.0845	0.0442	0.0749		0.0908	0.0766	0.0480	0.0205	0.0431	0.9993
London	0.0061	0.0035	0.0310	0.3658	0.0521	0.3227	0.0220	0.0847	0.0401	0.0091	0.0631	1.0002
Windsor	0.1357	0.0458	0.1006	0.1415	0.1052	0.0548	0.0879	0.0554	0.0400	0.1734	0.0599	1.0002
Sudbury	0.0067		0.0660	0.0133		0.0007	0.0082		0.4871	0.4144	0.0046	1.0010
Thunder Bay			0.2503			0.0104	0.6446		0.0765		0.0175	0.9993
Montreal	0.4967	0.0053	0.0559	0.0481	0.0140	0.0078	0.0215	0.0296	0.1033	0.0696	0.1484	1.0002
Total	0.9998	1.0001	1.0001	1.0000	1.0001	0.9999	1.0001	1.0000	1.0000	1.0000	1.0001	

where d_{ij} = the Euclidean distance between the destination interaction probability characteristics of two census tracts i and j

k = the destination zone under consideration for a particular origin zone (i or j)

p_{ik} = the bi-proportionally balanced interaction probability between origin zone i and destination zone k

That is, d_{ij} is a measure of the similarity in the destination probability vectors of two population centres being considered for potential merger into a cluster. If the destination probability vectors were identical then $d_{ij} = 0$. The lower the magnitude of d_{ij} the greater the similarity between the two census tracts. A detailed description of the clustering procedure is provided by Hutchinson and Smith (1979).

The distance measure calculated by equation (5.1) tends to increase as more population centres are included in a cluster. The clustering procedure groups zones so as to minimize the increase in the error across the entire set of population centres. One might expect that the first steps in a cluster hierarchy would consist of the pair-wise fusion of centres with a small increase in the error.

The interaction probability matrices presented in Tables 5.4, 5.5 and 5.6 were modified before the cluster analysis by removing Montreal and the intra-zonal effects by further bi-proportional balancing. Table 5.7 illustrates the interaction probabilities for total tonnes shipped. The destination probability vectors illustrated in Table 5.7 were used in the cluster analysis along with similar vectors for Commodity Groups 4 and 5.

Figure 5.1 shows the cluster hierarchy for the total tonnes shipped interaction probabilities. St. Catharines-Niagara Falls and Kitchener had the most similar destination probabilities followed by Oshawa and London, and Toronto and Windsor. The diagram illustrates that the fourth stage of the fusion was between the Toronto-Windsor cluster and Hamilton. The hierarchical structure illustrated in Figure 5.1 suggests five principal clusters and these are:

TABLE 5.7 Interaction Probabilities, Total Tonnes (Statistics Canada)

	Ottawa-Hull	Oshawa	Toronto	Hamilton	St. Cath.-N.Y.	Kitchener	London	Windsor	Sudbury	Thunder Bay	Total
Ottawa-Hull		0.0022	0.1620	0.0534	0.0260	0.0820	0.0428	0.2657	0.3387	0.0268	0.9996
Oshawa	0.2915		0.0849	0.1332	0.1534	0.1714	0.0288	0.1074	0.0257	0.0035	0.9998
Toronto	0.1362	0.0608		0.1105	0.0680	0.1032	0.1168	0.0661	0.1074	0.2312	1.0002
Hamilton	0.0295	0.0714	0.1350		0.2870	0.1154	0.0713	0.1206	0.0557	0.1137	0.9996
St. Cath.-N.Y.	0.0247	0.3526	0.0866	0.1997		0.0388	0.1268	0.0987	0.0553	0.0174	1.0006
Kitchener	0.0796	0.3555	0.0842	0.1545	0.0252		0.1440	0.0890	0.0500	0.0185	1.0005
London	0.1181	0.0044	0.0830	0.1183	0.1382	0.2704		0.1857	0.0256	0.0558	0.9995
Windsor	0.1869	0.1456	0.0686	0.0709	0.1873	0.0437	0.1881		0.0188	0.0902	1.0001
Sudbury	0.1327		0.2194	0.0308	0.1150	0.0004	0.0084	0.0497		0.4430	0.9994
Thunder Bay	0.0007	0.0075	0.0762	0.1287		0.1747	0.2730	0.0170	0.3227		1.0005
Total	0.9999	1.0000	0.9999	1.0000	1.0001	1.0000	1.0000	0.9999	0.9999	1.0001	

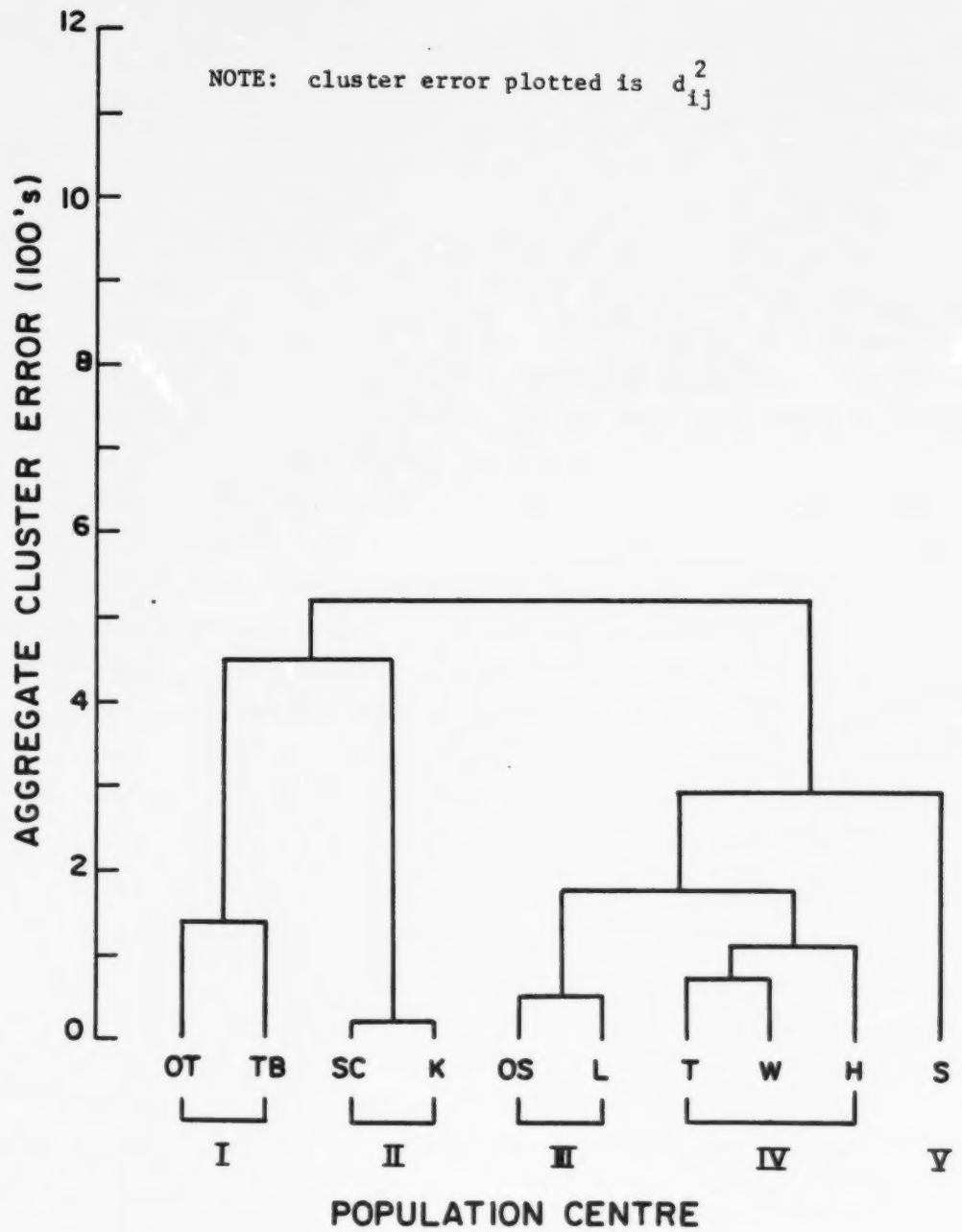


Figure 5.1 - Cluster Hierarchy for Total Tonnes Destination Probabilities

- I : Ottawa, Thunder Bay
- II : St. Catharines-Niagara Falls and Kitchener
- III : Oshawa and London
- IV : Toronto, Windsor and Hamilton
- V : Sudbury

Cluster I emerges from the strong destination association of the two communities with Sudbury and this association is probably accessibility related along the Trans-Canada Highway. Cluster II emerges from the strong destination associations between the two communities and Oshawa, Hamilton and London and the role of both of the population centres in auto parts manufacturing. The Oshawa and London association in Group III is related to their relatively strong and common interaction probabilities with Ottawa-Hull, Hamilton, St. Catharines-Niagara Falls, Kitchener and Windsor. These probably reflect the Oshawa and London involvement in automobile manufacturing. The associations between Toronto, Windsor and Hamilton in Group 4 are less clear since there are no really dominant and common interaction probabilities. They each have strong manufacturing bases and may simply reflect the dominance of Group 4 commodities in the for-hire truck market. The isolation of Sudbury in Cluster V reflects its very strong destination associations with Thunder Bay and Toronto.

Figures 5.2 and 5.3 illustrate the cluster hierarchies that emerged from Group 4 and Group 5 destination probability similarities, respectively. Both diagrams illustrate that in both cases there is more heterogeneity in the shipping patterns than for total commodities. This increased heterogeneity no doubt reflects differences in the market structures for the different commodity groups, but also differences in the statistical reliability of these stratified data bases.

Figure 5.2 illustrates that the first fusion occurs between St. Catharines-Niagara Falls and Kitchener, Toronto and Sudbury, Hamilton merging with the St. Catharines-Kitchener cluster, and Ottawa and Thunder Bay. Six clusters are identified in Figure 5.2. The association in Cluster III is due to relatively strong common destination probabilities with Toronto, London and Windsor, reflecting no doubt particular manufacturing linkages. The Cluster V association between Toronto and Sudbury

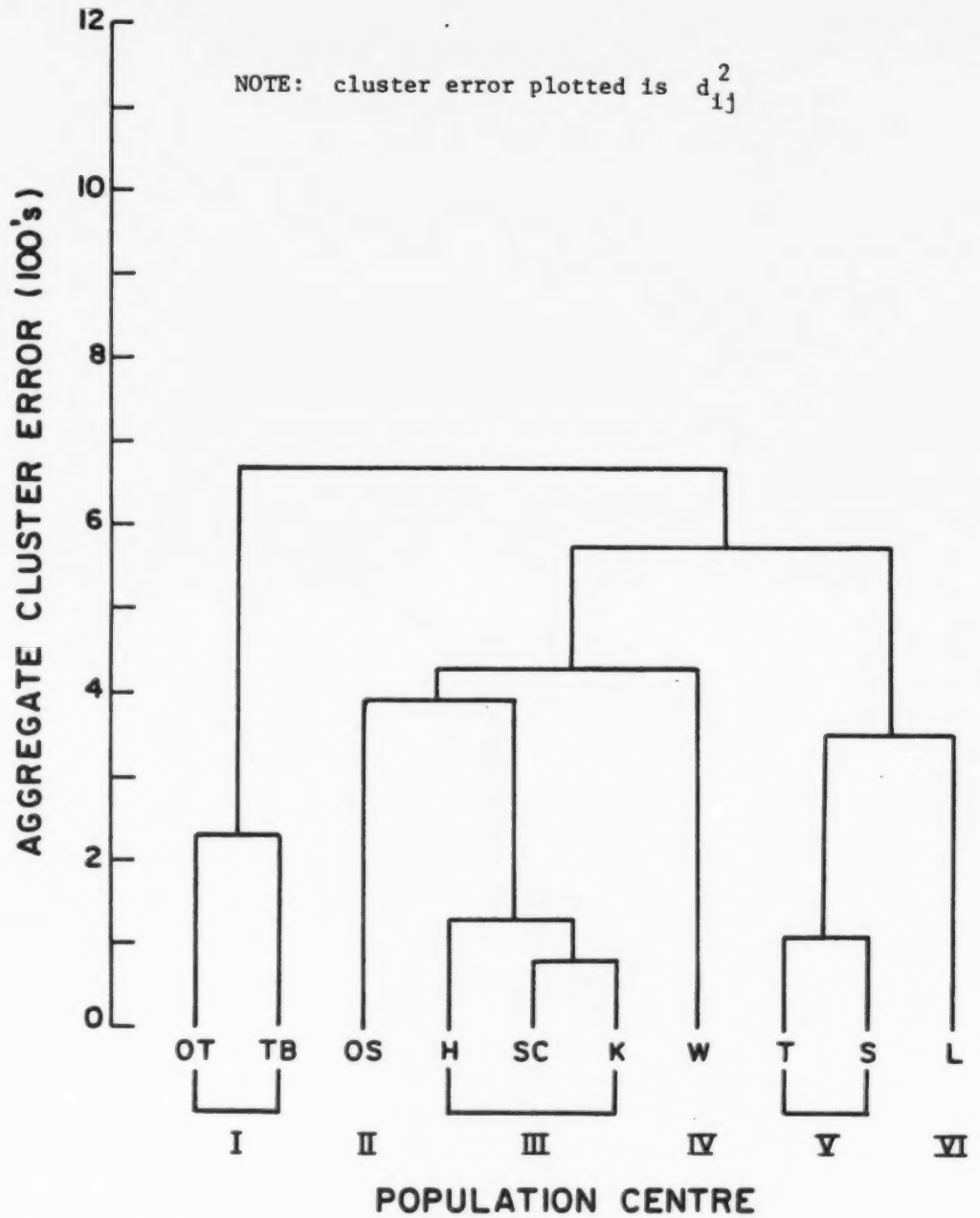


Figure 5.2 - Cluster Hierarchy for Group 4 Destination Probabilities

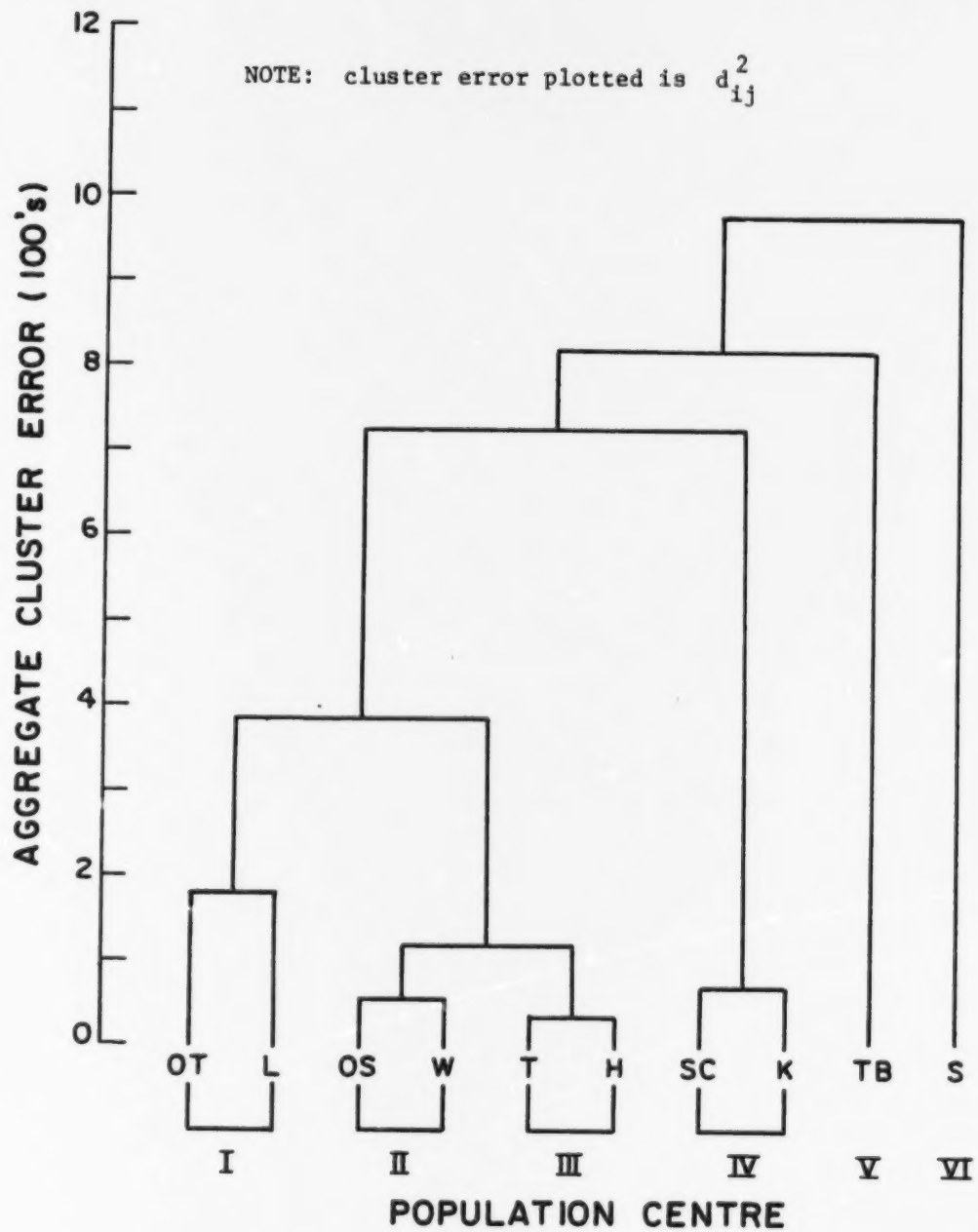


Figure 5.3 - Cluster Hierarchy for Group 5 Destination Probabilities

relates to a very strong common destination association with Thunder Bay. Figure 5.2 illustrates that sharp increases in the aggregate cluster error occurs before these seven clusters eventually merge.

Figure 5.3 illustrates that for Group 5 commodity shipments (primary metal, metal fabricating) three clusters emerge at relatively low cluster errors and these are Oshawa-Windsor, Toronto-Hamilton and St. Catharines-Kitchener. Cluster II emerges from strong destination probability associations with Ottawa-Hull, Hamilton and St. Catharines-Niagara Falls. Cluster III emerges from common destination associations with St. Catharines-Niagara Falls, Sudbury and Ottawa-Hull, while Cluster IV emerges from a very strong common destination linkage with Oshawa. The Group 5 clusters are quite dissimilar in character and only fuse at very large increases in the aggregate cluster error.

5.4 Observations on Interaction Patterns

The most important conclusion that emerges from the analyses presented in this chapter is that commodity shipment interaction patterns are more strongly related to the industrial structure of Ontario rather than to some simple spatial interaction hypothesis. This observation is confirmed by Figure 5.4 which illustrates the total commodity shipment interaction probability versus the interaction distance. This suggests that the estimation of future truck flow patterns depends very heavily on developing a very clear understanding of the structure of the Ontario trucking market. Additional interpretation is provided at the end of Chapter 6 where comparisons are made between the interaction structure suggested by the Statistics Canada survey and the interaction structure revealed by the MTC inspection station-based survey.

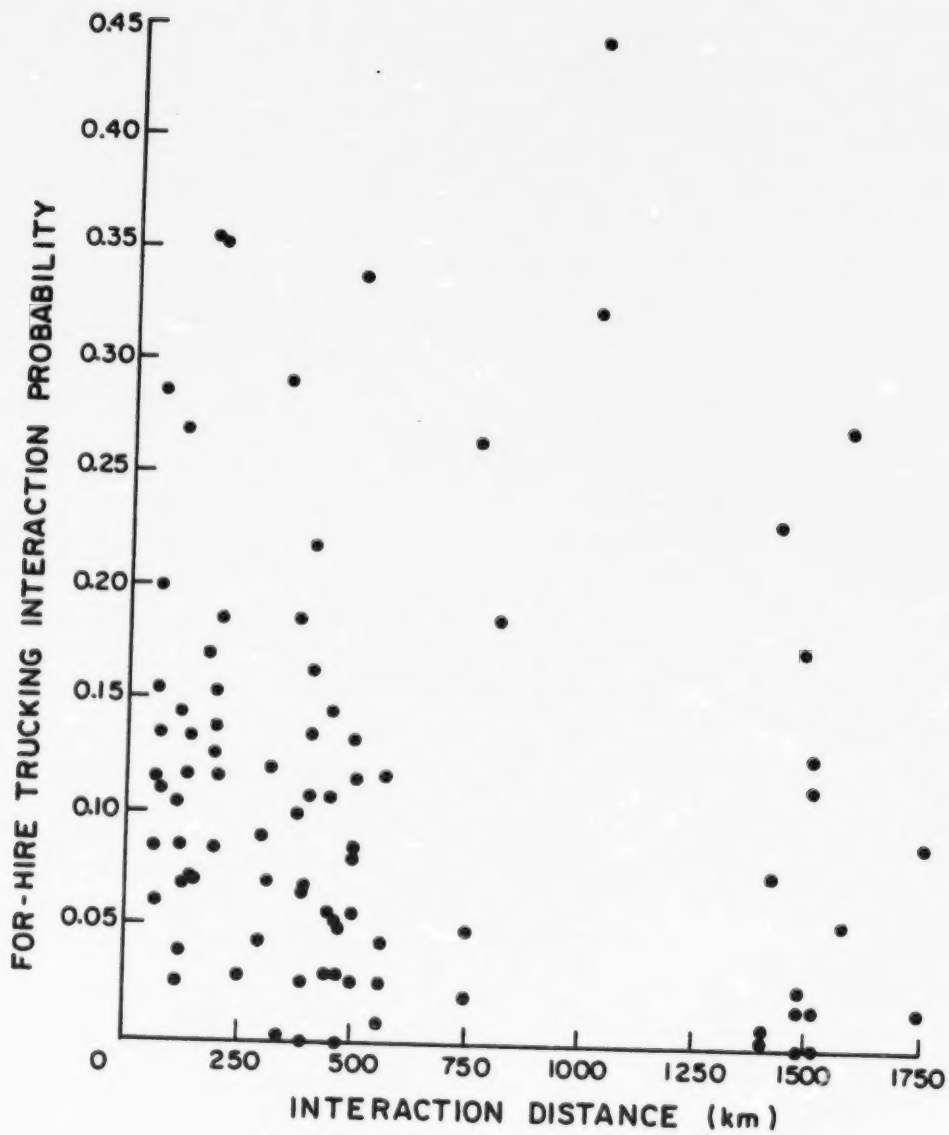


Figure 5.4 - For-Hire Trucking Interaction Probability vs Interaction Distance

CHAPTER 6

ANALYSES OF MTC 1978 COMMERCIAL VEHICLE SURVEY

6.1 Survey Data

The 1978 Commercial Vehicle Survey conducted by the Ontario Ministry of Transportation and Communications was carried out between May and November, 1978, at 37 truck inspection stations on the major Ontario highways. A total of 9,666 truck drivers were interviewed and a variety of information about truck ownership, commodities carried, payload, trip length and so on recorded. These data have been aggregated to the same system of Ontario population centres used in the Statistics Canada survey and Tables 6.1 and 6.2 summarize these interaction flows for for-hire trucks and private trucks, respectively.

6.2 Truck Trip Attraction Equations

Regression analyses of the truck trip attraction totals have been performed in terms of population and truck registrations with the following results:

$$\text{Truck Attractions} = -1204.8 + 0.0266 \times \text{Truck Registrations} \quad (6.1)$$

$$r^2 = 0.90 \quad t = 8.2 \quad s_e = 938 \text{ trips}$$

$$\text{Truck Attractions} = 409.89 + 0.00324 \times \text{Population} \quad (6.2)$$

$$r^2 = 0.96 \quad t = 14.2 \quad s_e = 563 \text{ trips}$$

The regression equation estimated in terms of manufacturing man-hours has not been included because of its inferior statistical qualities.

Figures 6.1 and 6.2 illustrate these relationships graphically, and reflect the superior statistical qualities of equation (6.2). Inspection of Figure 6.2 illustrates that equation (6.2) under-estimates the number of truck trips attracted to Oshawa, Windsor and Hamilton and over-estimates those to Thunder Bay, St. Catharines and Ottawa. The

TABLE 6.1 Total For-Hire Vehicle Flows, MTC 1978
(Number of movements in 600 hours May-November)

	Ottawa-Hull	Ottawa	Toronto	Hamilton	St. Cath.-N.Y.	Kitchener	London	Windsor	Sudbury	Thunder Bay	Unknown	Total
Ottawa-Hull	137	44	438	56	19	20	39	37	15	4	126	935
Ottawa	37	45	198	34	22	40	36	55	7		153	627
Toronto	255	199	1,440	551	198	197	274	336	175	32	470	4,127
Hamilton	66	79	550	110	32	6	37	57	30	3	180	1,150
St. Cath.-N.Y.	23	69	435	89	24	27	20	43	12	1	74	817
Kitchener	15	32	252	14	10	13	29	34	15	4	41	459
London	16	53	228	22	18	7	32	63	7	2	75	523
Windsor	48	128	363	77	34	40	75	224	21	12	72	1,094
Sudbury	21	13	193	29	4	40	9	9	136	9	29	492
Thunder Bay	8		31							81	35	155
Unknown	215	133	634	164	76	73	74	90	15	22	386	1,882
Total	841	795	4,762	1,146	437	463	625	948	433	170	1,641	12,261

NOTE: private trucks represented 51% of the total truck movements surveyed.

TABLE 6.2 Total Private Vehicle Flows, MTC 1978
(Number of movements in 600 hours May-November)

	Ottawa-Hull	Oshawa	Toronto	Hamilton	St. Cath.-N.Y.	Kitchener	London	Windsor	Sudbury	Thunder Bay	Unknown	Total
Ottawa-Hull	255	28	368	52	19	29	32	14	20		232	1,049
Oshawa	14	97	184	46	20	9	36	13			35	454
Toronto	225	488	1,364	869	306	330	270	168	170	8	729	4,927
Hamilton	38	97	973	143	35	6	25	32	43	3	106	1,501
St. Cath.-N.Y.	12	11	305	83	12	23	22	5	14	5	49	541
Kitchener	14	39	429	3	16	30	23	27	8	1	86	676
London	35	32	217	42	16	32	113	62	8		52	609
Windsor	35		147	15	14	26	53	304			75	669
Sudbury	8	6	120	28	6	21	14	23	214	4	42	486
Thunder Bay			9			1	1		14	179	13	217
Unknown	338	111	968	190	64	156	93	82	52	52	335	2,441
Total	974	909	5,084	1,471	508	663	682	730	543	252	1,754	13,570

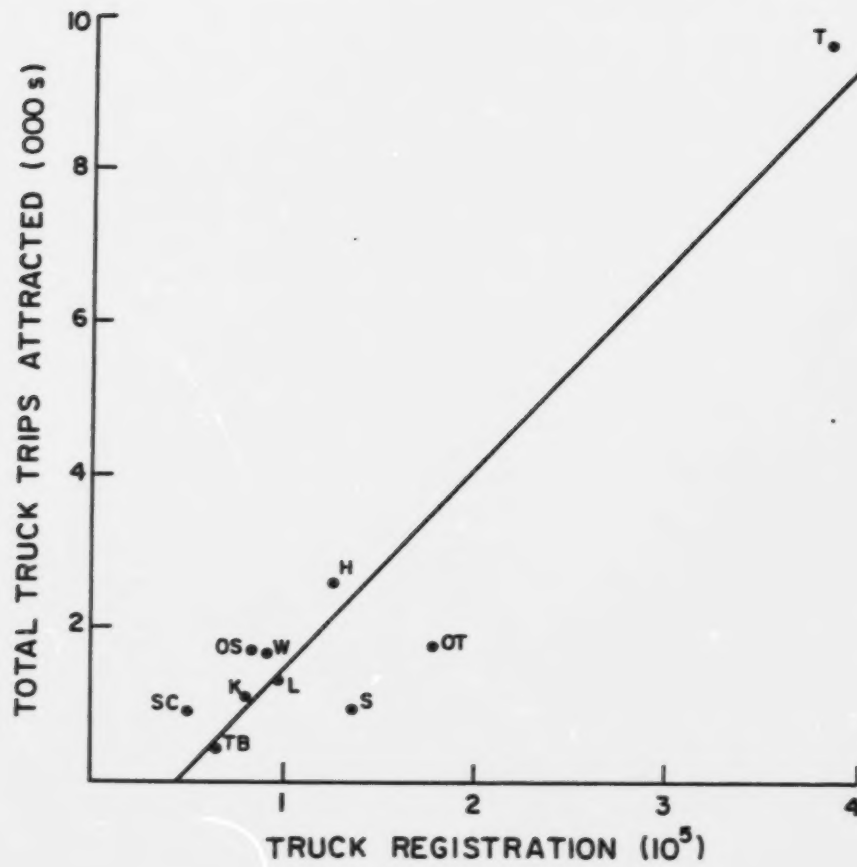


Figure 6.1 - Total Truck Trips Attracted vs Truck Registration

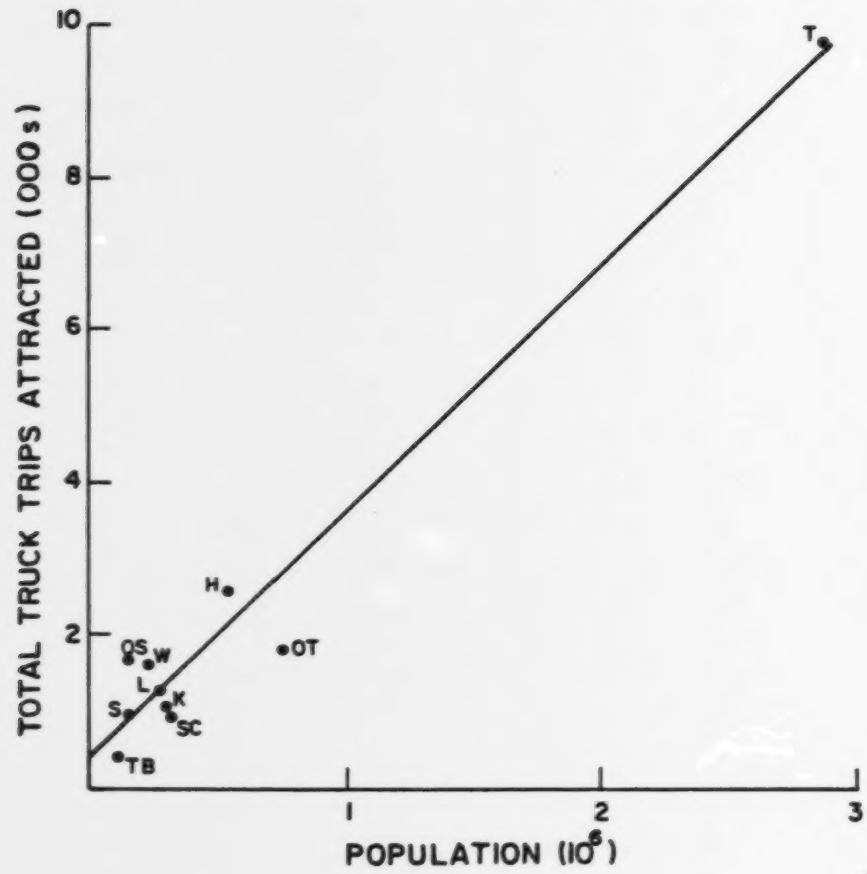


Figure 6.2 - Total Truck Trips Attracted vs Population

under-estimation residuals are related to the industrial activities in the communities mentioned above, while the over-estimation residual associated with Ottawa is clearly related to the absence of any significant manufacturing base.

Figures 6.3 and 6.4 illustrate respectively the relationships between the number of for-hire truck trips attracted and population, and the number of private truck trips attracted and population, where the relevant regression equations are:

$$\text{For-Hire Truck Trips Attracted} = 171.96 + 0.00157 \times \text{Population} \quad (6.3)$$

$$r^2 = 0.96 \quad t = 13.3 \quad s_e = 293 \text{ trips}$$

$$\text{Private Truck Trips Attracted} = 236.55 + 0.00167 \times \text{Population} \quad (6.4)$$

$$r^2 = 0.96 \quad t = 14.4 \quad s_e = 287 \text{ trips}$$

The standard errors of the above equations and the relationships illustrated in Figures 6.3 and 6.4 illustrate that the stratification of truck trip attractions into for-hire and private trucks does improve the overall explanatory powers of the equations.

Figure 6.3 illustrates that for-hire truck trips attracted to Oshawa and Windsor are under-estimated, no doubt reflecting their roles as automobile assembly centres. Truck trip attractions to Thunder Bay and to Ottawa are over-estimated reflecting high rail usage to and from Thunder Bay and the small manufacturing component of Ottawa's economic base. Similar residuals may be detected for the private truck trip attractions illustrated in Figure 6.4.

6.3 Truck Trip Generation Equations

The truck trip generation equations developed from the MTC commercial vehicle survey are:

$$\text{Truck Trips Generated} = 1,002.9 + 0.0243 \times \text{Truck Registrations} \quad (6.5)$$

$$r^2 = 0.89 \quad t = 8.2 \quad s_e = 864 \text{ trips}$$

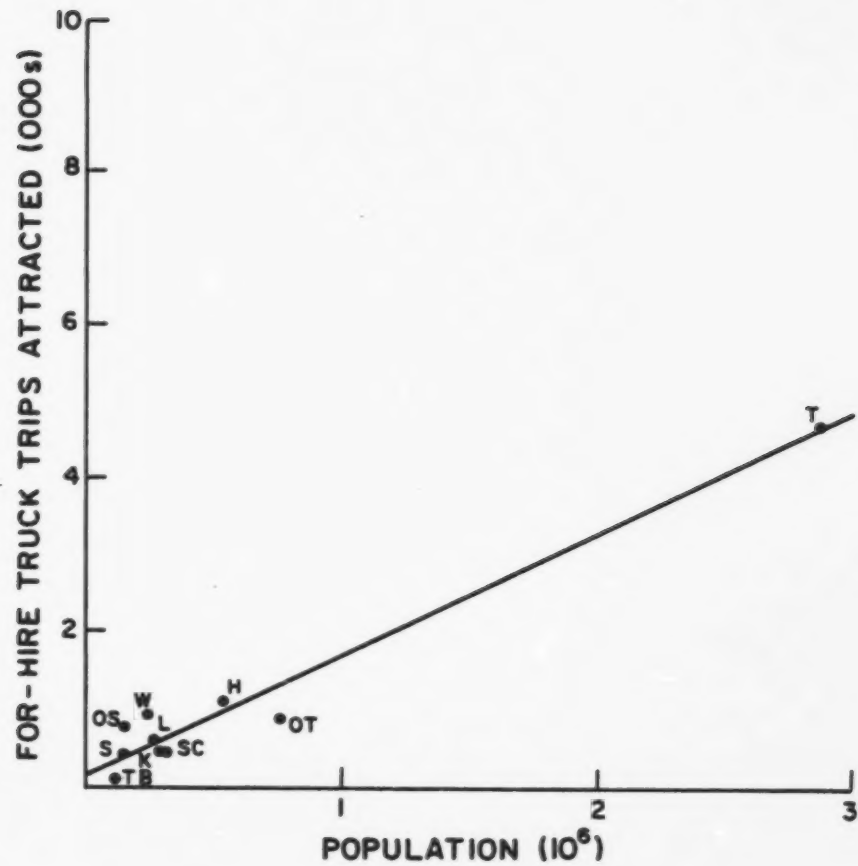


Figure 6.3 - For-Hire Truck Trips Attracted vs Population

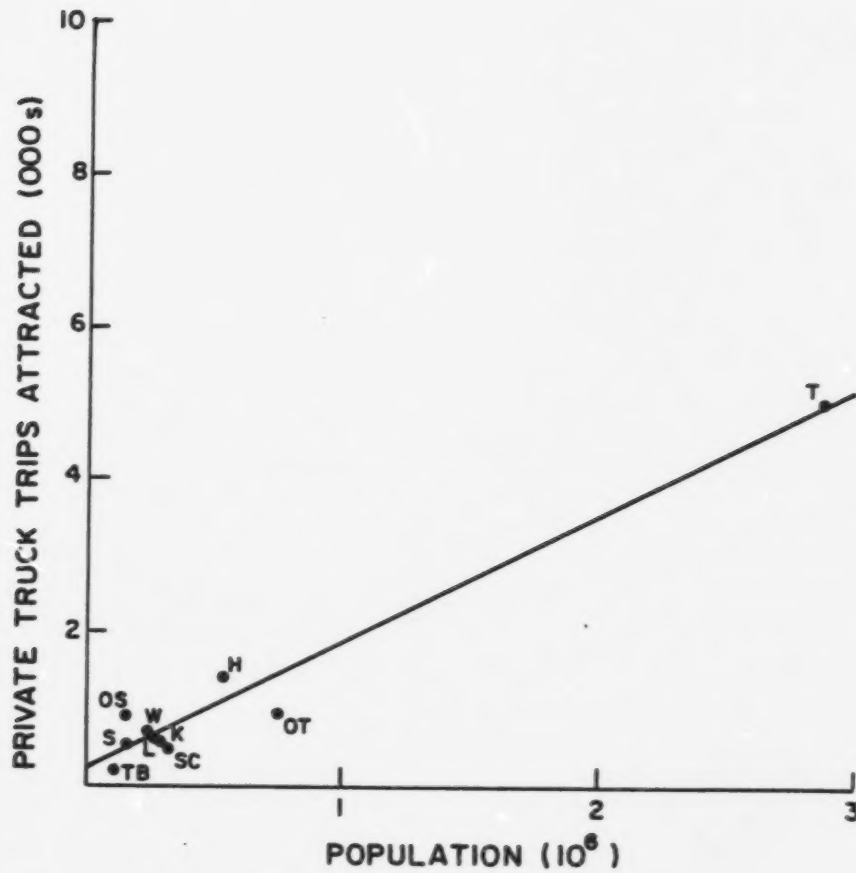


Figure 6.4 - Private Truck Trips Attracted vs Population

$$\text{Truck Trips Generated} = 461.3 + 0.00298 \times \text{Population} \quad (6.6)$$

$$r^2 = 0.97 \quad t = 17.5 \quad s_e = 423 \text{ trips}$$

Figures 6.5 and 6.6 illustrate the relationships graphically, and Figure 6.6 reflects the superior statistical qualities of equation (6.6). A pattern of residuals similar to those identified for the truck trip attraction equations are suggested to be under-estimated for the manufacturing communities, and over-estimated for Thunder Bay and Ottawa. It is also interesting to note that the generation rate indicated by equation (6.6) is about 6 percent lower than the attraction rate of equation (6.2), which reflect some of the attraction/generation biases of Table 6.1.

Figures 6.7 and 6.8 illustrate the relationships respectively between for-hire truck trip generations and population, and private truck trip generations and population, where the associated regression equations are:

$$\text{For-Hire Trips Generated} = 285.5 + 0.00133 \times \text{Population} \quad (6.7)$$

$$r^2 = 0.95 \quad t = 12.6 \quad s_e = 262 \text{ trips}$$

$$\text{Private Truck Trips Generated} = 175.8 + 0.00165 \times \text{Population} \quad (6.8)$$

$$r^2 = 0.98 \quad t = 19.9 \quad s_e = 215 \text{ trips}$$

Once again the principal residuals are associated with the population centres identified previously.

6.4 Bi-Proportional Matrices

Tables 6.3 and 6.4 illustrate the bi-proportionally balanced interaction tables for for-hire trucks and private trucks respectively with the unknown entries included, while Tables 6.5 and 6.6 exclude the unknown row and column entries. Substantial unknown entries exist for both attractions and generations for Ottawa-Hull and generations from Windsor and Thunder Bay.

Comparisons of the interaction probabilities of Table 6.5 with those of Table 5.7 derived from the Statistics Canada survey showed no significant degrees of association. Figure 6.9 shows the MTC private trucking interaction probabilities versus the for-hire trucking probab-

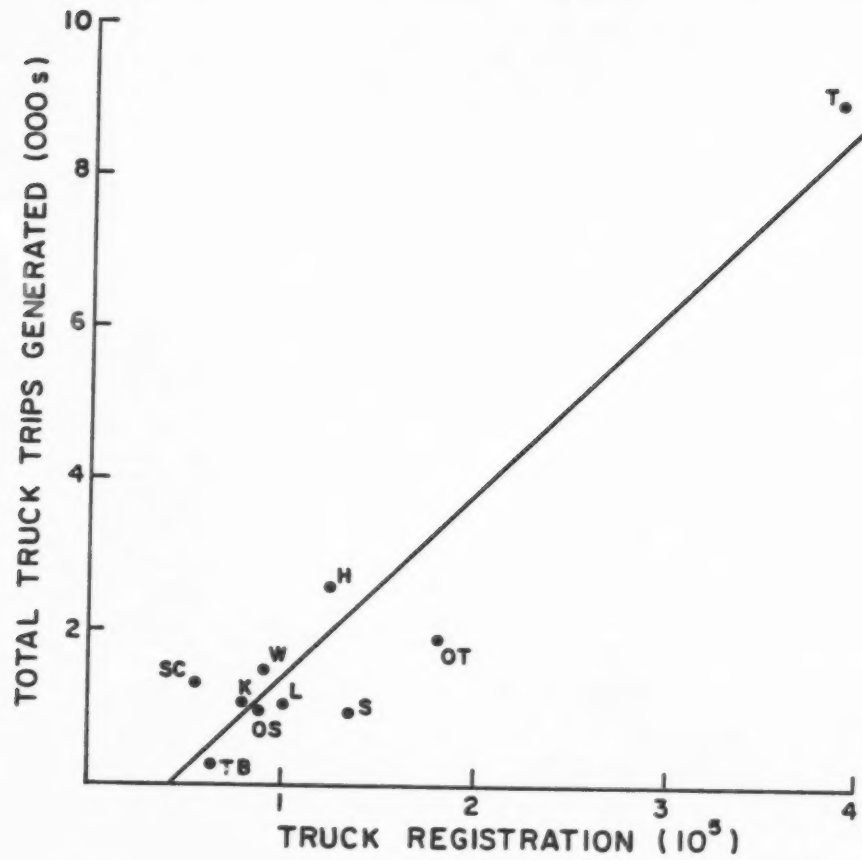


Figure 6.5 - Truck Trips Generated vs Truck Registration

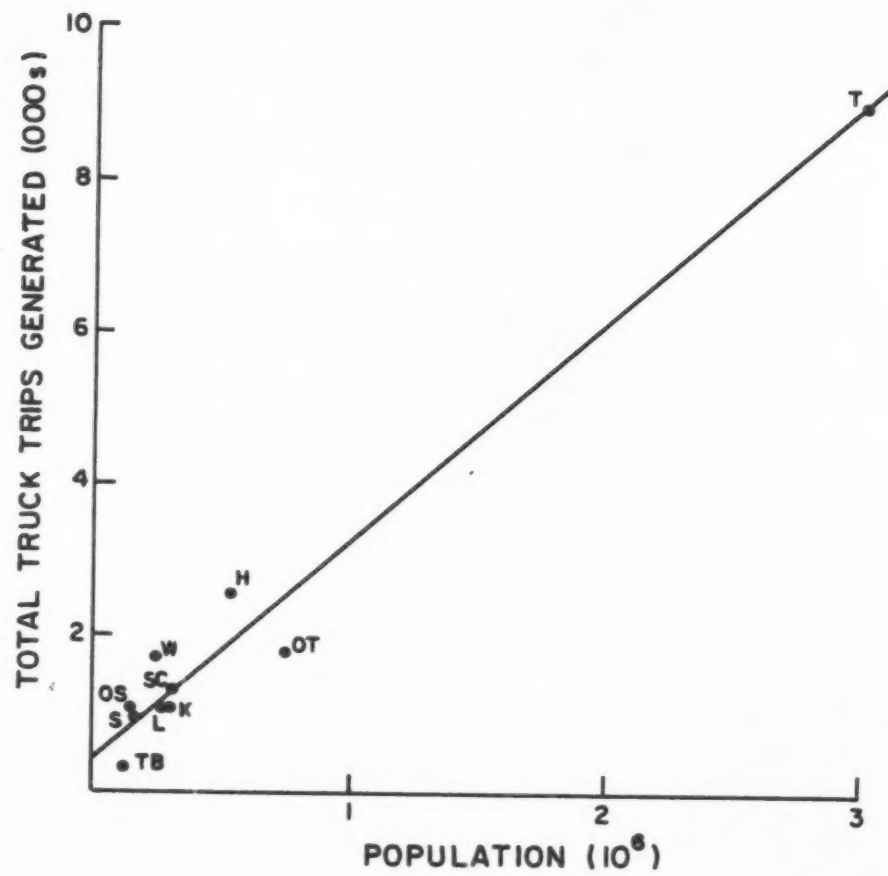


Figure 6.6 - Truck Trips Generated vs Population

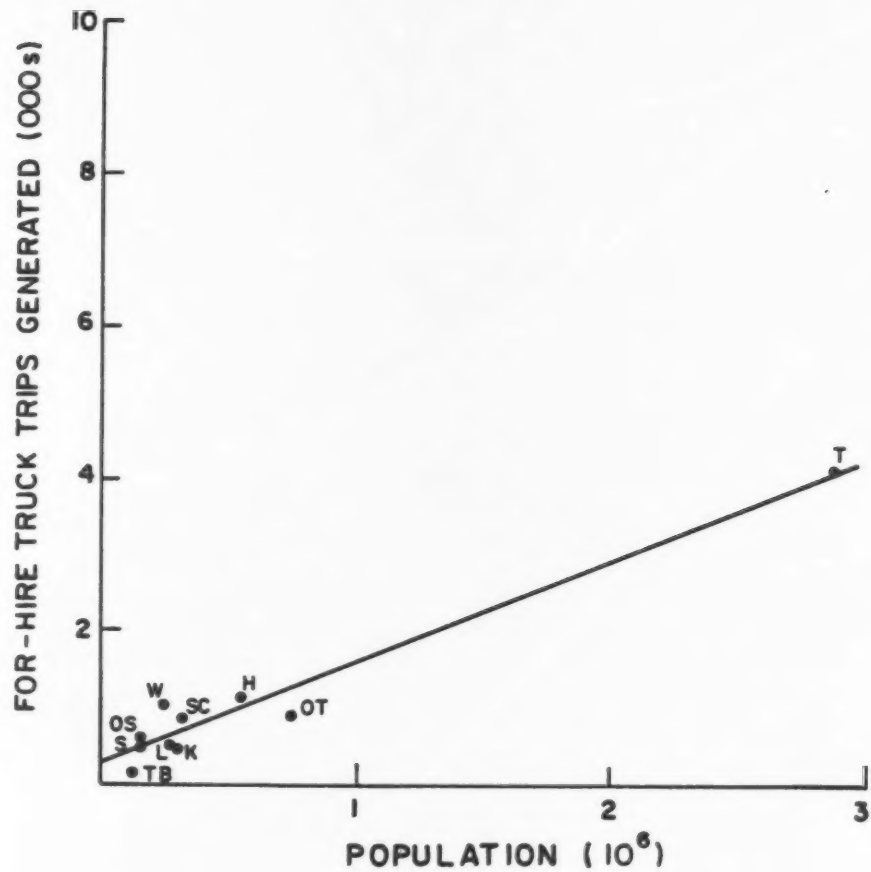


Figure 6.7 - Truck Trips Generated vs Population

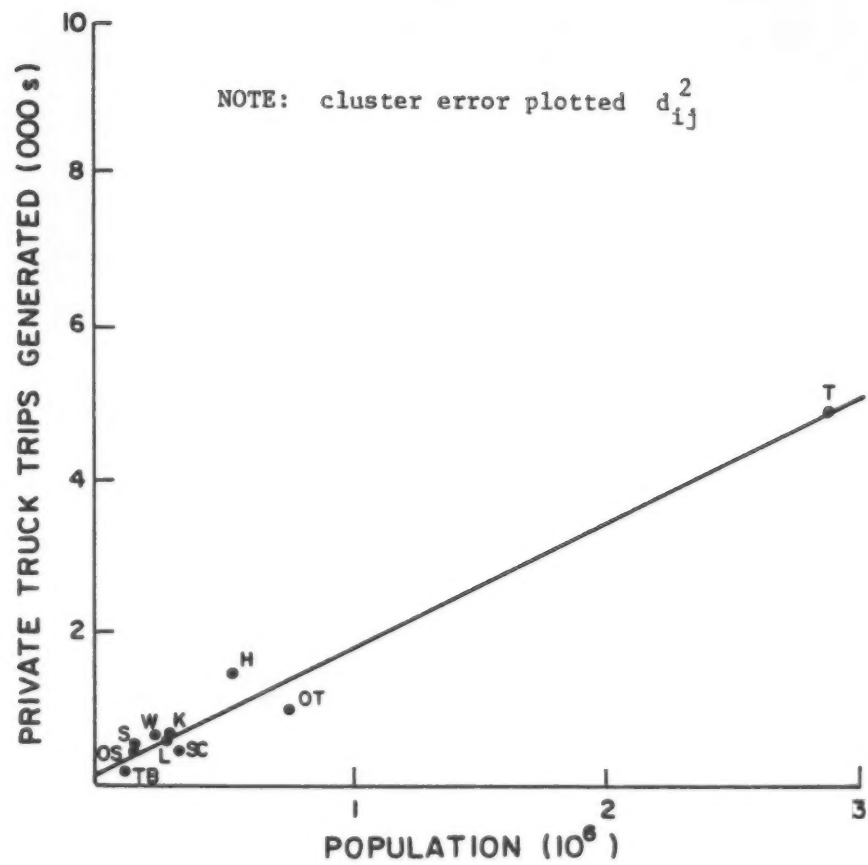


Figure 6.8 - Private Truck Trips Generated vs Population

TABLE 6.3 Interaction Probabilities, For-Hire Trucking (MTC)

	Ottawa-Hull	Oshawa	Toronto	Hamilton	St. Cath.-N.F.	Kitchener	London	Windsor	Sudbury	Thunder Bay	Unknown	Total
Ottawa-Hull		0.0920	0.1177	0.1204	0.1001	0.0803	0.1321	0.0867	0.1128	0.0798	0.0782	1.0001
Oshawa	0.0831		0.0609	0.0837	0.1327	0.1837	0.1395	0.1476	0.0602		0.1086	1.0000
Toronto	0.0634	0.0527		0.1500	0.1321	0.1001	0.1175	0.0998	0.1666	0.0809	0.0369	1.0000
Hamilton	0.1003	0.1279	0.1144		0.1306	0.0186	0.0970	0.1035	0.1747	0.0464	0.0865	0.9999
St. Cath.-N.F.	0.0485	0.1550	0.1256	0.2056		0.1164	0.0728	0.1083	0.0970	0.0214	0.0493	0.9999
Kitchener	0.0458	0.1041	0.1053	0.0468	0.0820		0.1528	0.1240	0.1755	0.1242	0.0396	1.0001
London	0.0476	0.1678	0.0927	0.0716	0.1436	0.0425		0.2236	0.0797	0.0604	0.0704	0.9999
Windsor	0.0568	0.1612	0.0537	0.0997	0.1079	0.0967	0.1530		0.0951	0.1442	0.0269	1.0002
Sudbury	0.0672	0.0443	0.0845	0.1017	0.0344	0.2617	0.0497	0.0344		0.2928	0.0293	1.0000
Thunder Bay	0.3432		0.1820								0.4743	0.9995
Unknown	0.1441	0.0949	0.0581	0.1204	0.1367	0.1000	0.0855	0.0720	0.0385	0.1498		1.0000
Total	1.0000	0.9999	0.9999	0.9999	1.0001	1.0000	0.9999	0.9999	1.0001	0.9999	1.0000	

TABLE 6.4 Interaction Probabilities, Private Trucking (MTC)

	Ottawa-Hull	Oshawa	Toronto	Hamilton	St. Cath.-N.Y.	Kitchener	London	Windsor	Sudbury	Thunder Bay	Unknown	Total
Ottawa-Hull												
Oshawa	0.0969											
Toronto	0.0806	0.1771										
Hamilton	0.0900	0.2328	0.1899									
St. Cath.-N.Y.	0.0549	0.0510	0.1151	0.2145								
Kitchener	0.0696	0.1966	0.1759	0.0084	0.1123							
London	0.1373	0.1272	0.0702	0.0930	0.0886	0.1281						
Windsor	0.2155		0.0746	0.0521	0.1216	0.1633	0.2568					
Sudbury	0.0500	0.0380	0.0619	0.0989	0.0529	0.1340	0.0689	0.1646				
Thunder Bay			0.0426			0.0585	0.0452		0.6641			
Unknown	0.2052	0.0683	0.0484	0.0651	0.0548	0.0966	0.0444	0.0570	0.0261	0.3144		
Total	1.0000	0.9999	1.0000	1.0000	1.0000	1.0000	1.0000	0.9999	0.9999	1.0000	1.0001	

TABLE 6.5 Interaction Probabilities, For-Hire Vehicles (MTC)

	Ottawa-Hull	Oshawa	Toronto	Hamilton	St. Cath.-N.F.	Kitchener	London	Windsor	Sudbury	Thunder Bay	Total
Ottawa-Hull		0.1027	0.0971	0.1397	0.1160	0.0909	0.1457	0.0929	0.1177	0.0976	1.0003
Oshawa	0.0644		0.0532	0.1027	0.1627	0.2202	0.1630	0.1673	0.0666		1.0001
Toronto	0.0440	0.0558		0.1650	0.1451	0.1075	0.1229	0.1013	0.1649	0.0937	1.0002
Hamilton	0.0782	0.1519	0.1004		0.1610	0.0225	0.1139	0.1179	0.1940	0.0603	1.0001
St. Cath.-N.F.	0.0353	0.1720	0.1030	0.2371		0.1310	0.0798	0.1153	0.1006	0.0260	1.0001
Kitchener	0.0328	0.1137	0.0850	0.0531	0.0929		0.1649	0.1299	0.1792	0.1485	1.0000
London	0.0351	0.1887	0.0771	0.0837	0.1676	0.0485		0.2412	0.0838	0.0744	1.0001
Windsor	0.0390	0.1691	0.0455	0.1087	0.1175	0.1029	0.1586		0.0933	0.1656	1.0002
Sudbury	0.0459	0.0462	0.0651	0.1100	0.0371	0.2765	0.0511	0.0344		0.3339	1.0002
Thunder Bay	0.6252		0.3736								0.9988
Total	0.9999	1.0001	1.0000	1.0000	0.9999	1.0000	0.9999	1.0002	1.0001	1.0000	

TABLE 6.6 Interaction Probabilities, Private Vehicles (MTC)

	Ottawa-Hull	Oshawa	Toronto	Hamilton	St. Cath.-N.Y.	Kitchener	London	Windsor	Sudbury	Thunder Bay	Total
Ottawa-Hull		0.1451	0.1489	0.1539	0.1341	0.1531	0.1222	0.0835	0.0593		1.0001
Oshawa	0.1231		0.1063	0.1944	0.2016	0.0678	0.1963	0.1107			1.0002
Toronto	0.1019	0.1858		0.1891	0.1588	0.1280	0.0758	0.0736	0.0371	0.0502	1.0003
Hamilton	0.1126	0.2418	0.1893		0.1189	0.0152	0.0459	0.0918	0.0614	0.1233	1.0002
St. Cath.-N.Y.	0.0614	0.0474	0.1025	0.2041		0.1009	0.0698	0.0248	0.0345	0.3549	1.0003
Kitchener	0.0916	0.2146	0.1843	0.0094	0.1200		0.0933	0.1711	0.0252	0.0907	1.0002
London	0.1699	0.1307	0.0692	0.0980	0.0890	0.1332		0.2915	0.0187		1.0002
Windsor	0.2845		0.0785	0.0586	0.1304	0.1811	0.2670				1.0001
Sudbury	0.0549	0.0347	0.0541	0.0924	0.0472	0.1236	0.0596	0.1529		0.3809	1.0003
Thunder Bay			0.0670			0.0971	0.0702		0.7639		0.9982
Total	0.9999	1.0001	1.0001	0.9999	1.0000	1.0000	1.0001	0.9999	1.0001	1.0000	

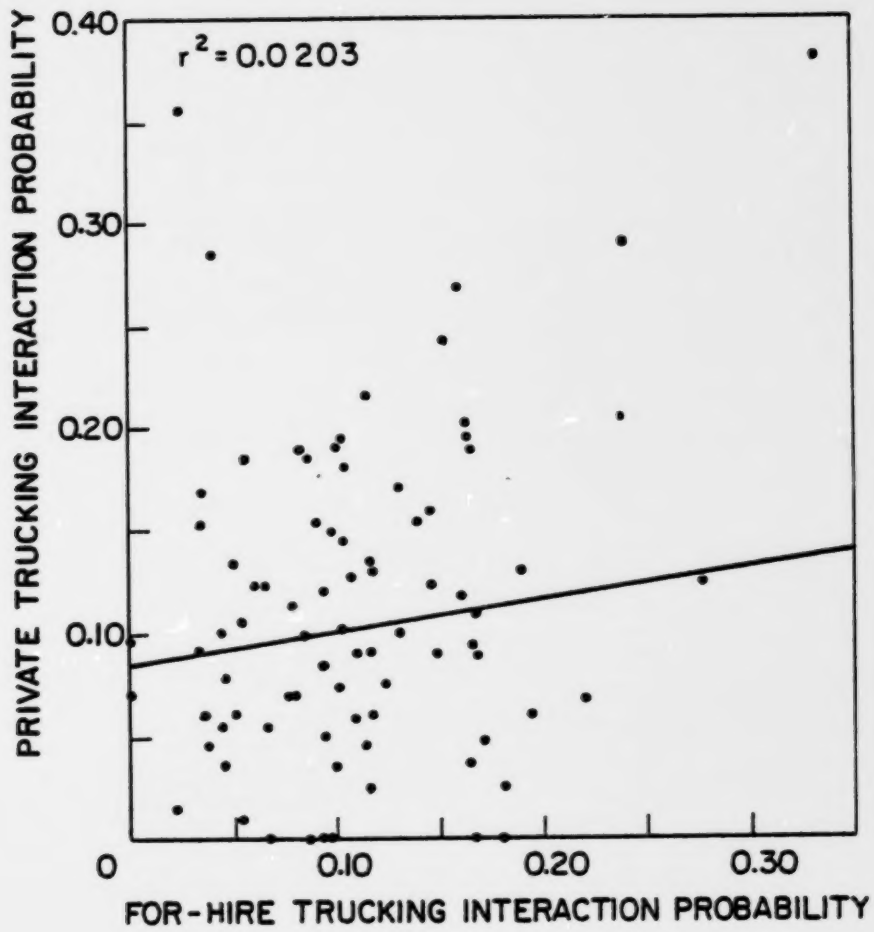


Figure 6.9 - MTC Private vs For-Hire Interaction Probabilities

ilities of Tables 6.6 and 6.5, respectively. The diagram illustrates that there is no significant degree of association between the two sets of interaction probabilities.

6.5 Cluster Analyses

Figures 6.10, 6.11 and 6.12 illustrate the cluster analysis dendrograms for the destination interaction probability vectors derived for for-hire trucks, private trucks and total truck movement, respectively. These dendrograms have a very different character from the dendrograms developed from the Statistics Canada survey data and illustrated in Figures 5.1, 5.2 and 5.3, respectively.

The first characteristic that may be noted from a comparison of the two sets of dendrograms is that the population centres cluster at a much smaller aggregate cluster error for the MTC survey than for the Statistics Canada survey except for the case of Thunder Bay. The second characteristic to be noted from the comparison is that population centres that cluster together are different between the two sets of interaction probabilities.

Four clusters may be identified in Figure 6.10 with Sudbury and Thunder Bay forming two of these clusters. Inspection of the interaction probabilities in Table 6.5 suggest that Hamilton, Kitchener and London cluster together on the basis of their common interaction magnitudes with Oshawa, St. Catharines-Niagara Falls and Windsor reflecting no doubt the for-hire trucking market provided by the auto industry. The five population centres contained in Group I cluster together mainly on the basis of the uniformity of the components of their destination probability vectors, with no individual interaction probabilities dominating. The isolation of Thunder Bay is due to the large number of zero entries in its destination probability vector.

Four clusters may be identified in the cluster hierarchy illustrated in Figure 6.11 for MTC private trucking destination probability vectors. The dendrogram illustrates that there is more diversity in the private trucking destination probability vectors

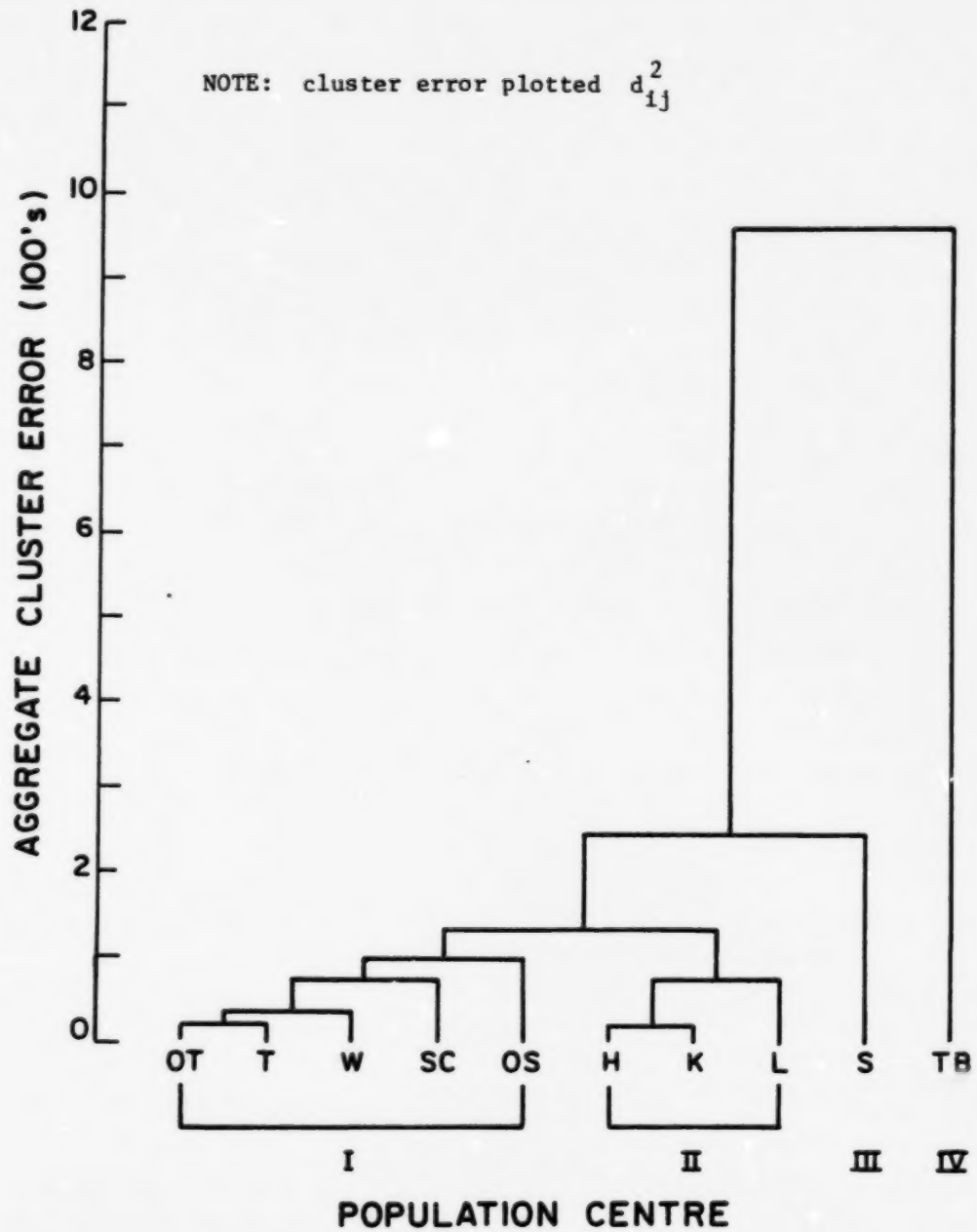


Figure 6.10 - Cluster Hierarchy for MTC For-Hire Trucking Destination Probabilities

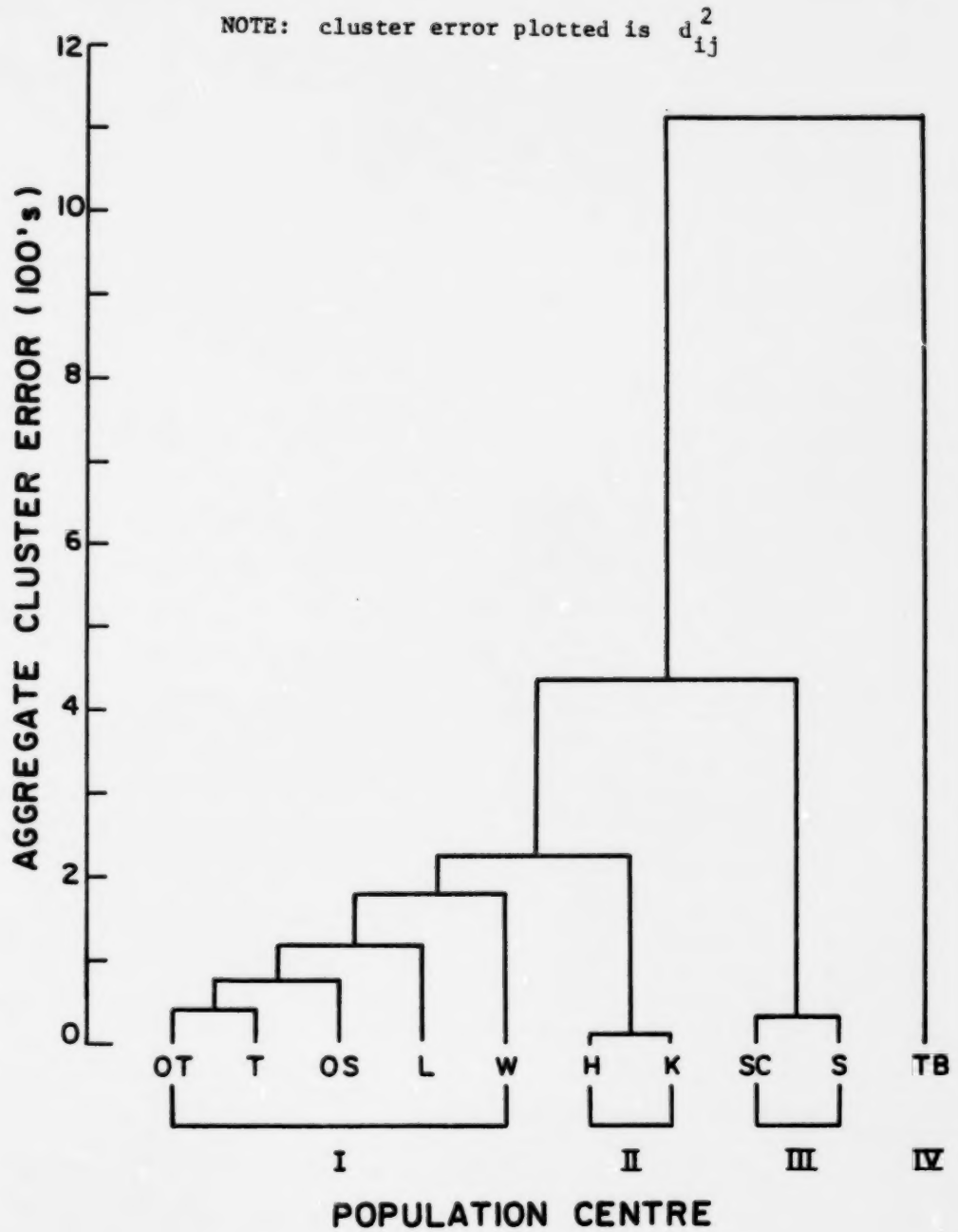


Figure 6.11 - Cluster Hierarchy for MTC Private Trucking Destination Probabilities

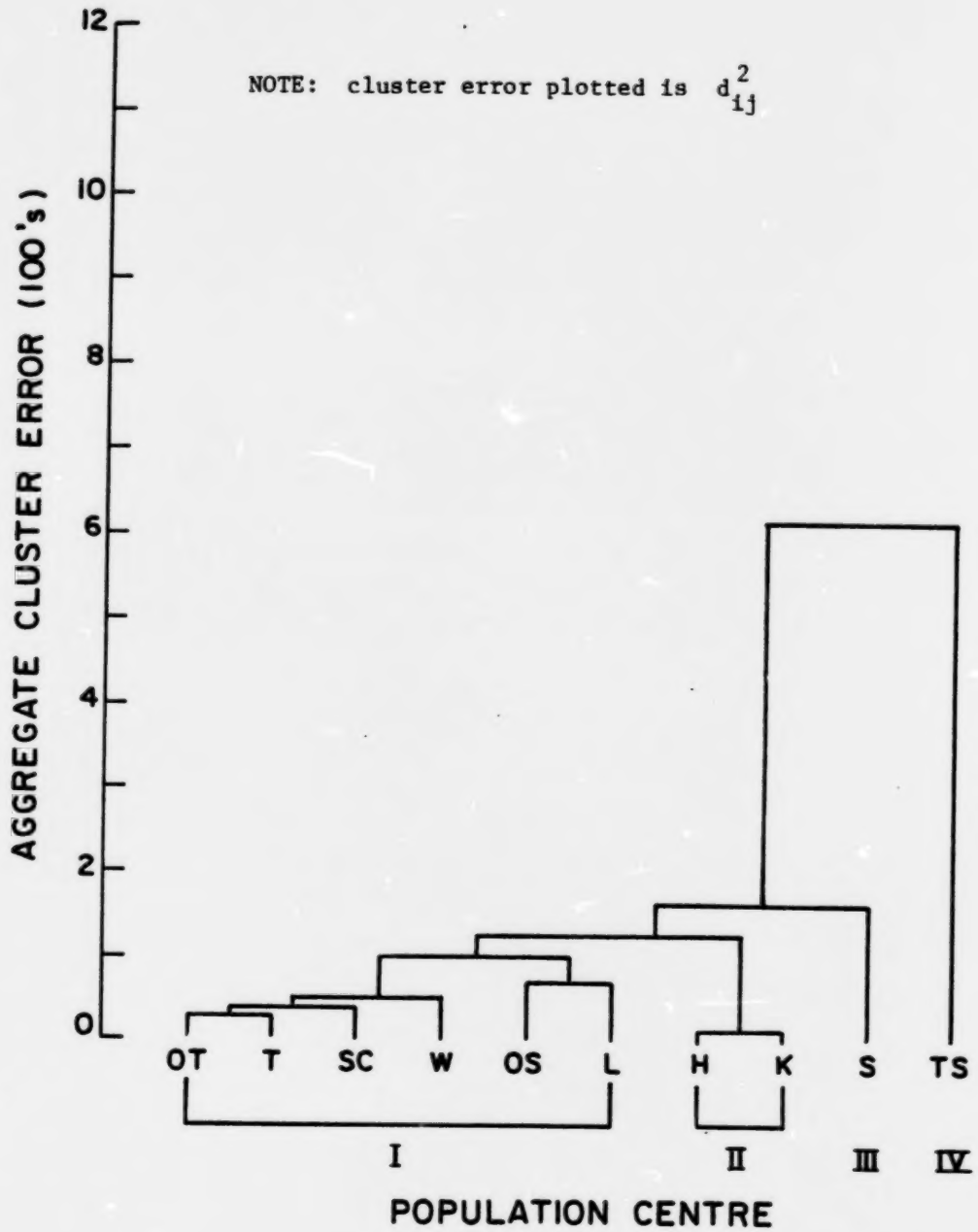


Figure 6.12 - Cluster Hierarchy for MTC Total Trucking Destination Probabilities

than in the for-hire vectors. Clusters form only at higher aggregation errors. There are some differences between the two dendrograms with London replacing St. Catharines-Niagara Falls in Group I and St. Catharines-Niagara Falls clustering with Sudbury. Inspection of Table 6.6 illustrates that the Hamilton-Kitchener cluster is on the basis of common interaction probability magnitudes with Oshawa and Toronto. The St. Catharines-Sudbury cluster is on the basis of a strong and common interaction probability with Thunder Bay.

Figure 6.12 shows a similar pattern of clustering to that illustrated in Figure 6.10 for for-hire trucks. Hamilton and Kitchener cluster together in one group and the other six southern Ontario population centres clustering together in a second group.

The differences between the cluster patterns obtained for the Statistic Canada and MTC data sets are related to the elements of the Ontario trucking market that each captures. It should be recalled that the dominant commodity group in the Statistics Canada survey was Group 4 (machinery, transport equipment and electrical products). This dominance was also reflected in the regression analyses presented in Chapter 4 where annual manufacturing man-hours was found to be a better explanatory variable than either population or truck registrations. The cluster pattern of destination probabilities reflected this bias in the data with the manufacturing-based population centres clustering together.

The MTC survey provided a more general sample of truck movements, rather than commodity movements. For-hire and private trucks engaged in the movement of a variety of commodity types were sampled and this is reflected in the regression analyses presented in this chapter, where population was found to be strongly correlated with truck attractions and truck generations. These characteristics of the MTC data base are also reflected in the cluster hierarchies just described.

6.6 Attraction, Generation Analyses at a Finer Spatial Scale

The truck origin-destination data collected in the 1978 MTC commercial vehicle survey were coded to a system of 73 population centres.

These data were aggregated to the ten Ontario population centre system for the analyses described in the previous sections in order to be compatible with the spatial system used for the Statistics Canada for-hire trucking data. The MTC data have also been analyzed at the finer spatial scale and the following regression analyses are for the 37 communities with truck trip generations of greater than 100 trips.

The following set of truck trip attraction equations have been developed for the data coded to the finer scale:

$$\text{Total Truck Trips Attracted} = 91.7 + 0.00337 \times \text{Population} \quad (6.9)$$

$$r^2 = 0.97 \quad t = 33 \quad s_e = 194 \text{ trips}$$

$$\text{For-Hire Truck Trips Attracted} = 94.1 + 0.00121 \times \text{Population} \quad (6.10)$$

$$r^2 = 0.94 \quad t = 23 \quad s_e = 123 \text{ trips}$$

$$\text{Private Truck Trips Attracted} = 58.9 + 0.00157 \times \text{Population} \quad (6.11)$$

$$r^2 = 0.98 \quad t = 38 \quad s_e = 95 \text{ trips}$$

These relationships are illustrated in Figures 6.13, 6.14 and 6.15, respectively.

Figure 6.13 illustrates a similar phenomenon shown by the more aggregate analyses described previously and this is the impact of the manufacturing sector on the rates of attraction. Figure 6.13 also illustrates that Brampton generated truck trip rates at a much higher per capita rate, reflecting the manufacturing activity in that area. The pattern of residuals in Figure 6.13 would suggest that an improved prediction equation could be developed if stratified employment data were available at this much finer scale. Similar effects may be detected in the relationships illustrated in Figures 6.14 and 6.15.

The following set of truck trip generation equations have been developed for the finer spatial scale:

$$\text{Total Truck Trips Generated} = 153.0 + 0.00278 \times \text{Population} \quad (6.12)$$

$$r^2 = 0.97 \quad t = 33 \quad s_e = 194 \text{ trips}$$

$$\text{For-Hire Truck Trips Generated} = 94.1 + 0.00121 \times \text{Population} \quad (6.13)$$

$$r^2 = 0.94 \quad t = 23 \quad s_e = 123 \text{ trips}$$

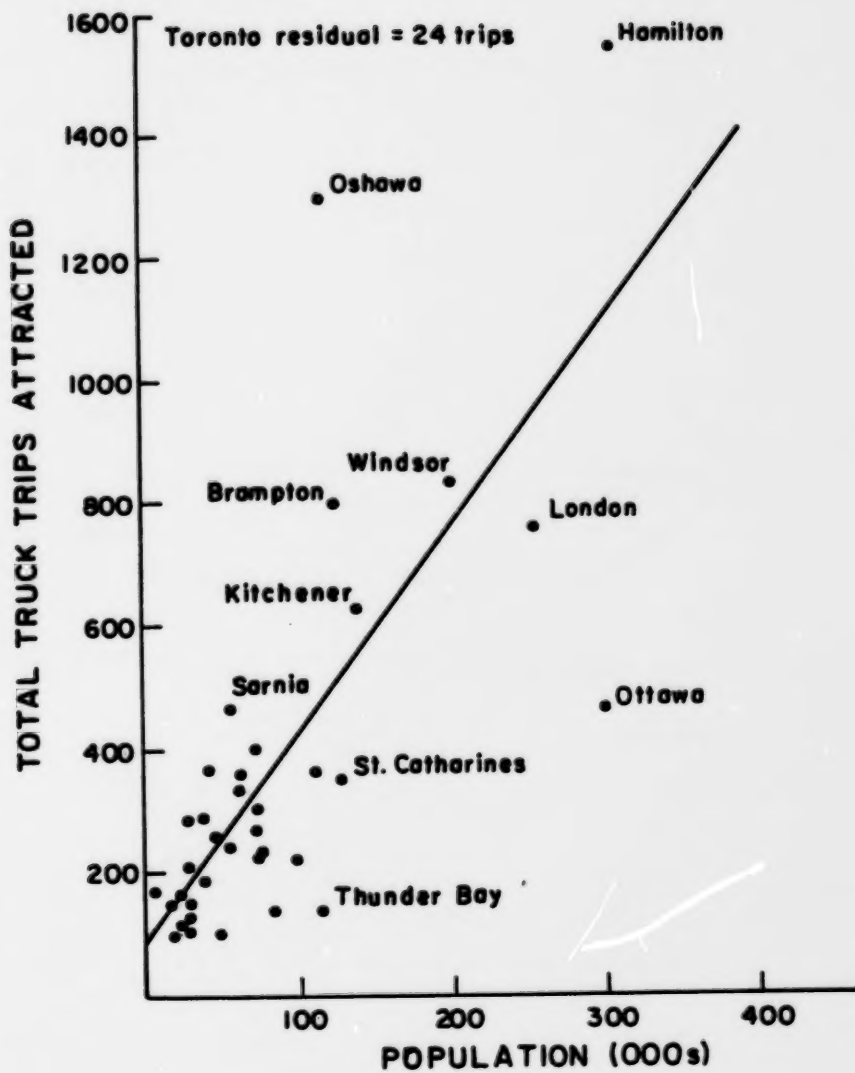


Figure 6.13 - Total Truck Trips Attracted vs Population

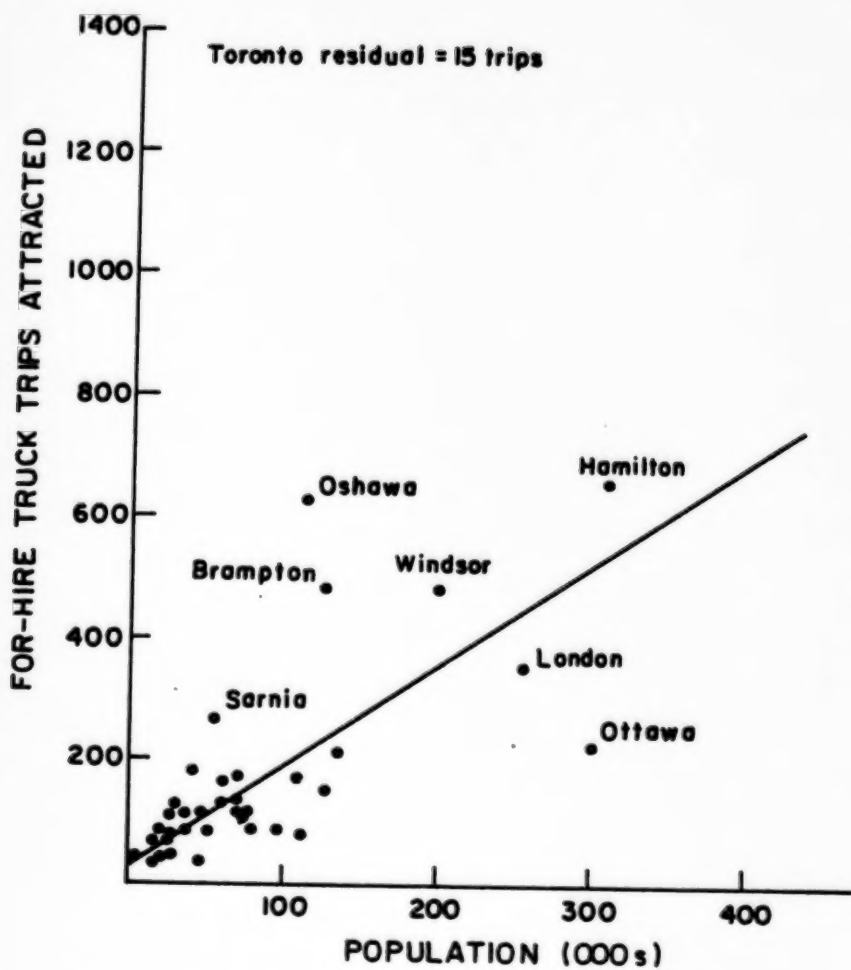


Figure 6.14 - For-Hire Truck Trips Attracted vs Population

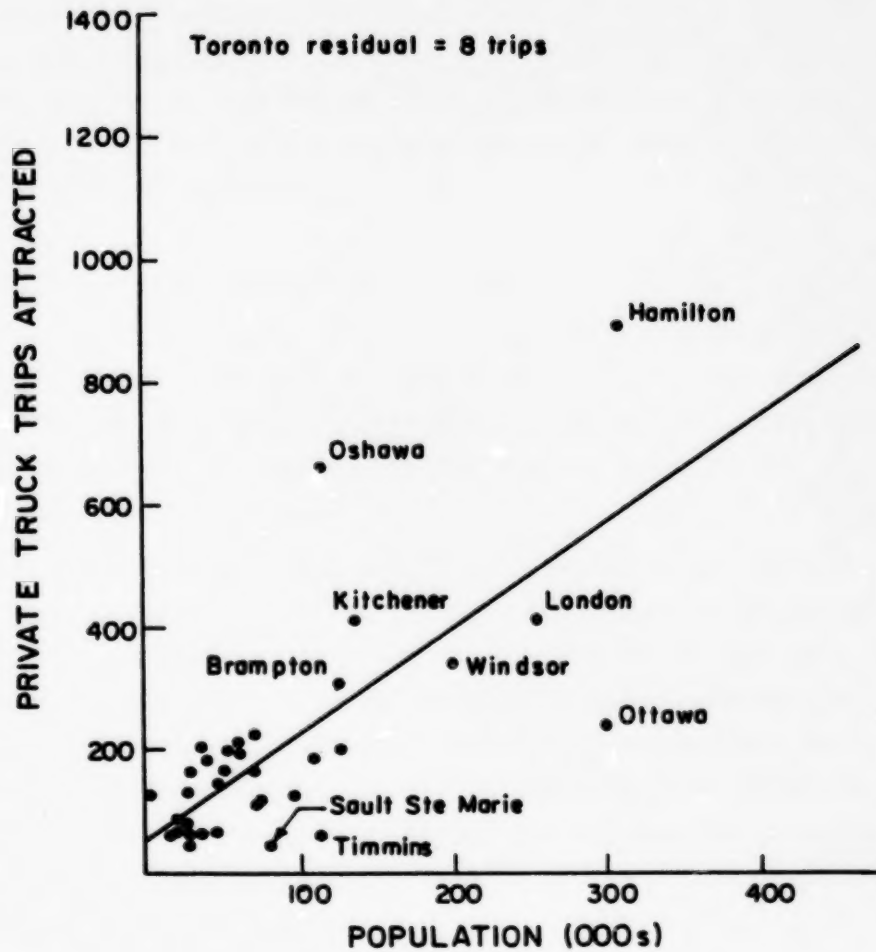


Figure 6.15 - Private Truck Trips Attracted vs Population

$$\text{Private Truck Trips Attracted} = 58.9 + 0.00157 \times \text{Population} \quad (6.14)$$

$$r^2 = 0.98$$

$$t = 39$$

$$s_e = 95 \text{ trips}$$

These relationships are illustrated in Figures 6.16, 6.17 and 6.18 respectively. The relationships illustrate once again the impact that the manufacturing employment base has on truck trip activity with those communities having automobile assembly plants generating very high per capita rates of truck trip attractions.

6.7 Observations on the Analyses of MTC Data

The data collected in the 1978 MTC commercial vehicle survey seem to provide a more reliable view of the trucking market in Ontario. However, because the data are available for only one point in time it is not possible to develop any feeling for the temporal stability of this trucking information.

The regression equations developed in terms of population at both spatial scales were of good overall statistical quality but a number of the population centres exhibited significant deviations from the Provincial-wide average generation and attraction rates. The spatial distribution of the automobile assembly plants and the component manufacturers is one of the principal features influencing truck movements in Ontario. Communities with no significant manufacturing component to their economic bases generated and attracted trucks at a much lower per capita rate.

The cluster analyses of the spatial interaction probabilities allowed communities with similar destination vectors to be identified, and these analyses confirmed the influence of the automobile manufacturing sector to the trucking industry.

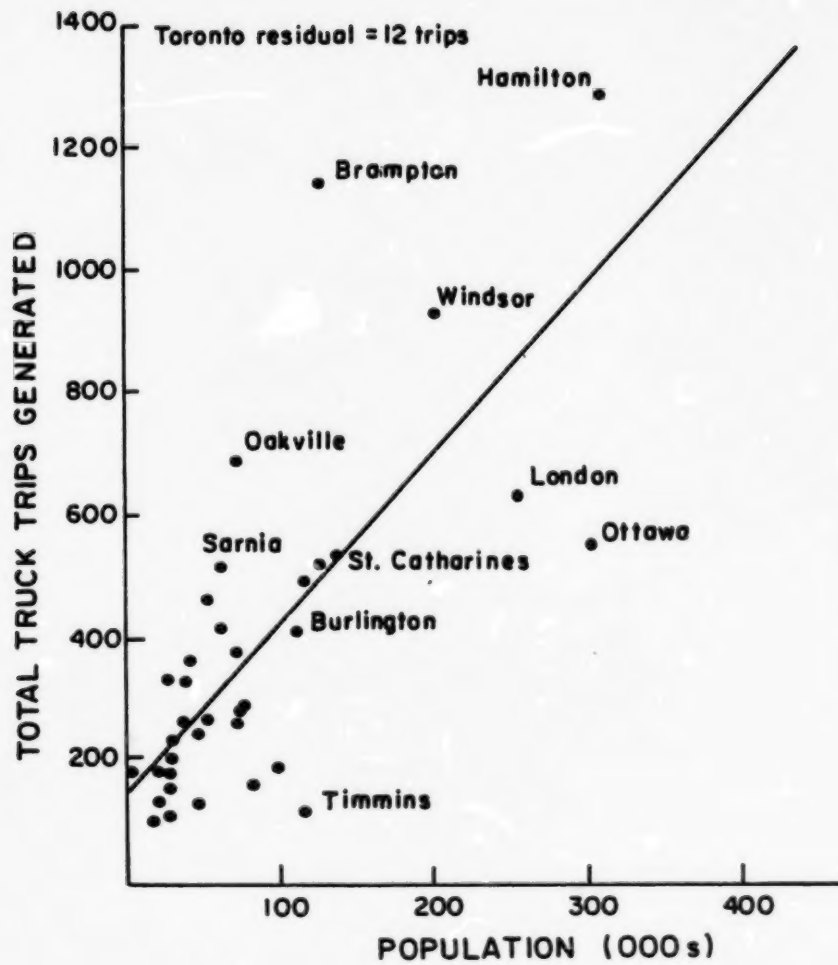


Figure 6.16 - Truck Trips Generated vs Population

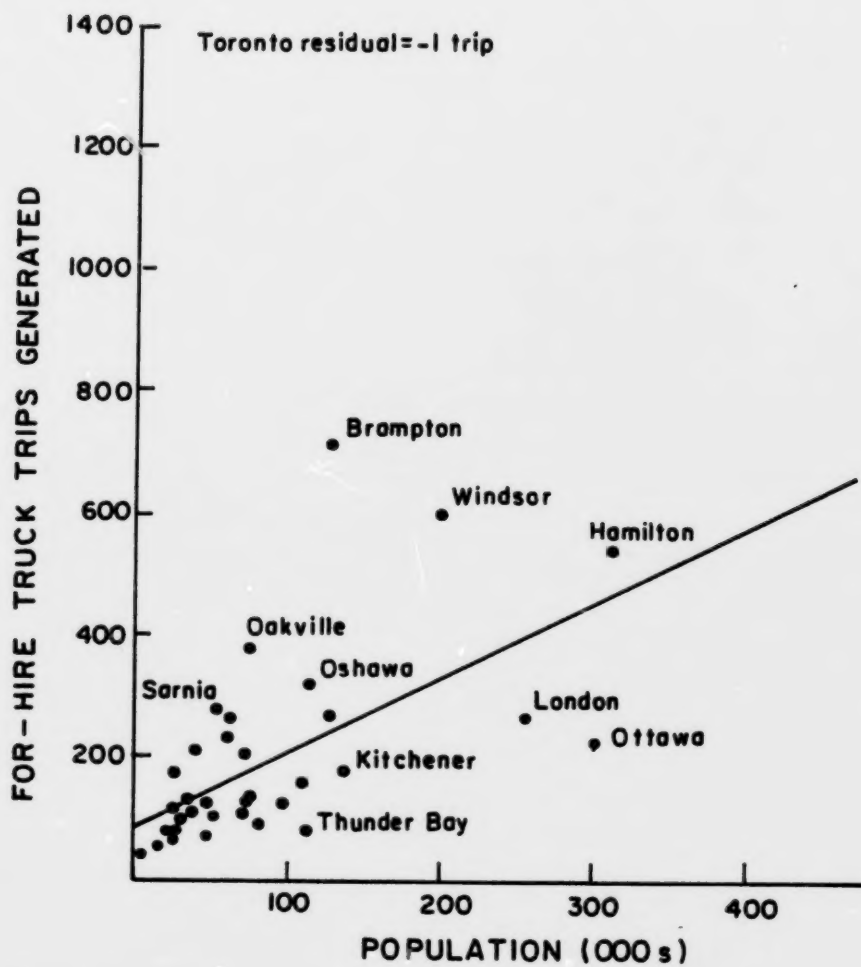


Figure 6.17 - For-Hire Truck Trips Generated vs Population

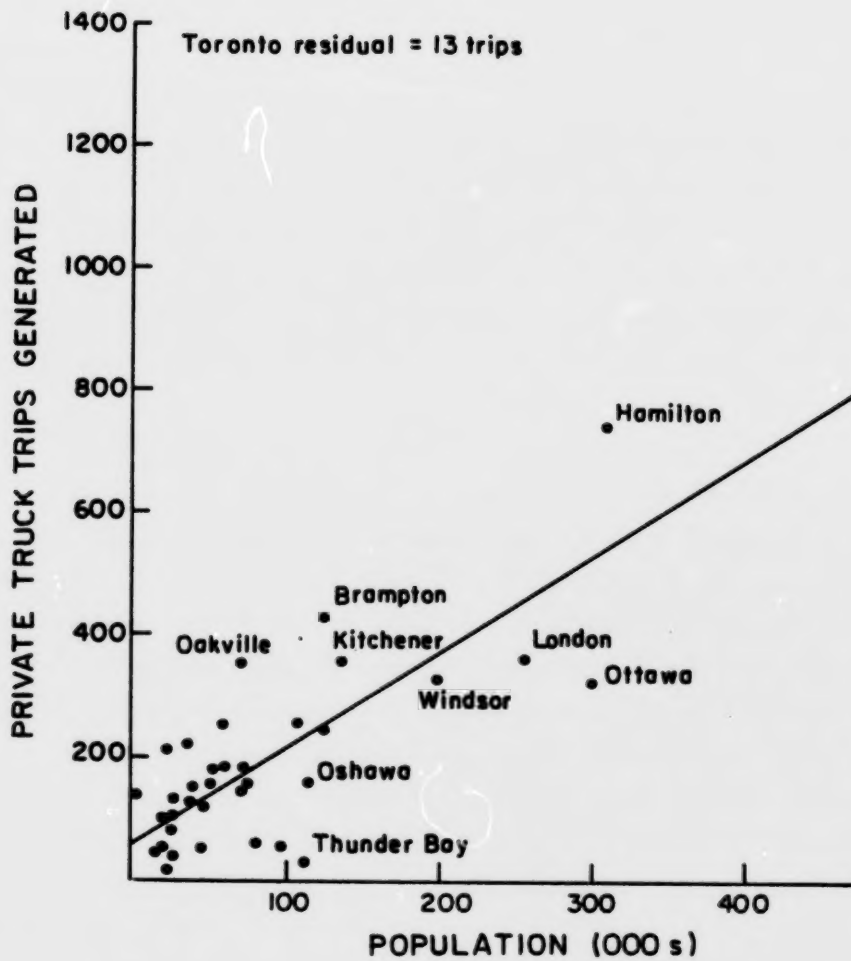


Figure 6.18 - Private Truck Trips Generated vs Population

CHAPTER 7

ADDITIONAL SOURCES OF INFORMATION

7.1 Introduction

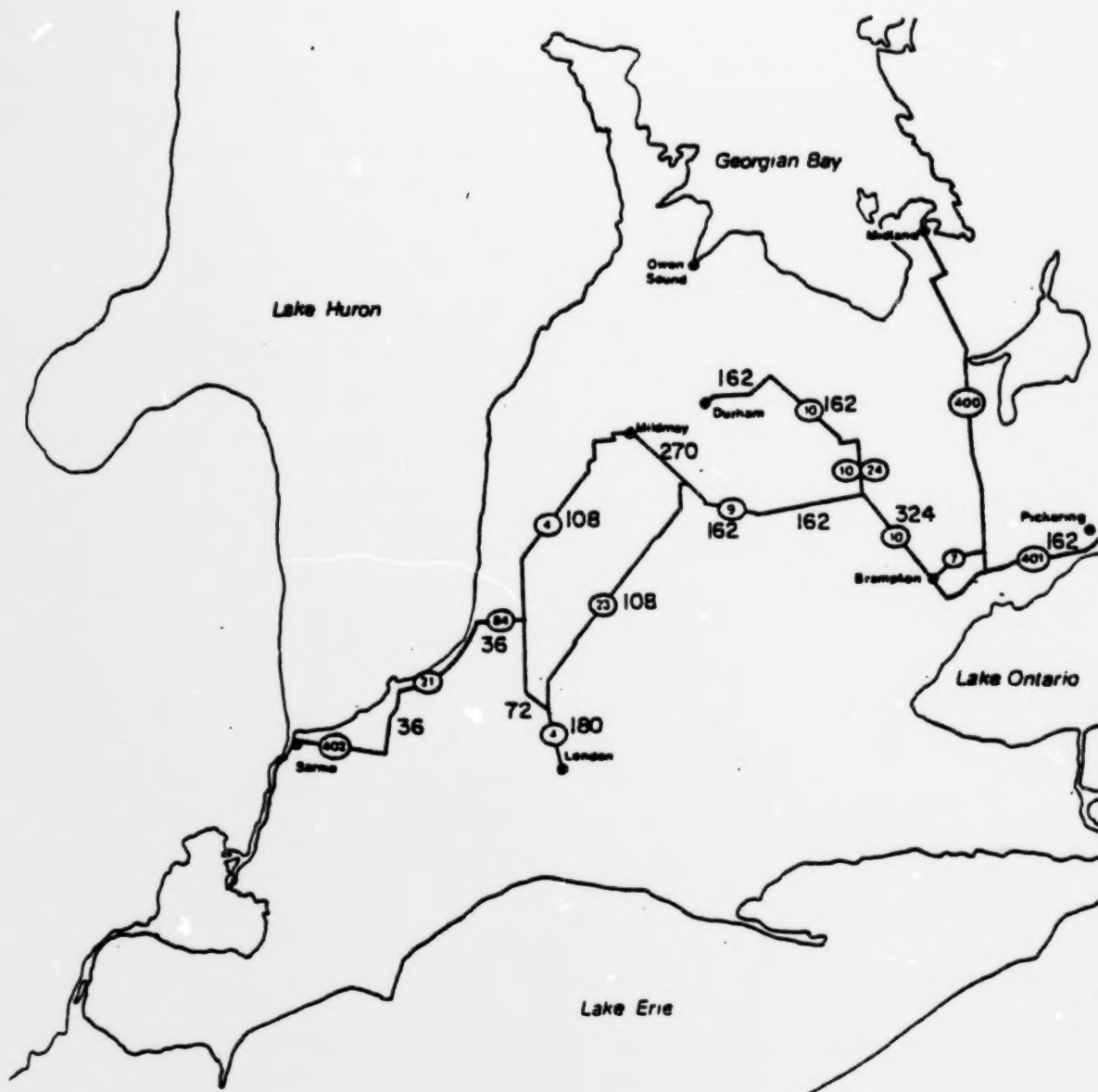
The previous chapters of this report have concentrated on the analysis of the two principal data bases available on inter-city truck movements in Ontario. This chapter provides a brief review of the other sources of information on truck movements that may supplement the data bases analyzed earlier. These additional data bases are not analyzed since they provide only very limited additional information.

7.2 Mineral Aggregate Transportation Study

The Ontario Ministry of Natural Resources funded a two year study of mineral aggregate requirements in Ontario, Ministry of Natural Resources Ontario (1980), and this report contains estimates of expected truck volumes generated by these mineral aggregate movements. The study estimated the future demand for mineral aggregates for four typical market areas of Ontario and these were Toronto, London, Windsor and Sarnia. The abilities of current sources of supply in the vicinities of these urban areas to satisfy these demands were then evaluated and the additional materials that would have to be supplied by long distance transport from sources in the Grey/Bruce/Huron Counties and Manitoulin Island areas estimated.

Estimates of the two-way peak hour truck volumes were prepared and Figure 7.1 illustrates the highway link flows estimated for 1993 between the supply and demand areas. The substantial volumes expected on the section of Highway 10 between Orangeville and Highway 401 should be noted. These peak-hour volumes were estimated by converting estimated annual tonnages in the following way.

A standard truck was assumed to be a 6-axle tractor-trailer unit carrying 35 tonnes with the monthly distribution of volumes shown in Table 7.1. It was assumed that there would be 21 working days per month,



Source: Ontario Ministry of Natural Resources (1980), "Mineral Aggregate Transportation Study", Final Report, December.

Figure 7.1 - Estimated Two-Way Hourly Truck Volumes for Mineral Aggregate Movements, 1993

TABLE 7.1 Assumed Monthly Distribution of Mineral
Aggregate Flows

Month	Percent of Annual Volume
January	3
February	3
March	3
April	5
May	10
June	11
July	12
August	12
September	12
October	12
November	11
December	6

Source: Ontario Ministry of Natural Resources (1980), op.cit.

that the peak day would be Friday with volumes 10 percent higher than the average day, and that the peak hour would be 20 percent greater than the average hour. Therefore, the two-way peak hour truck volume is given by:

Two-Way PH Truck Volume =

$$\left\{ \frac{\text{annual tonnage} \times 0.12 \times 1.10}{35 \times 21} \right\} \left\{ \frac{1.2 \times 2.0}{12} \right\}$$

$$= \text{annual tonnage in million tonnes} \times 180 \times 0.2$$

$$= \text{annual tonnage in million tonnes} \times 36$$

where the quantity inside the first set of brackets represents the peak daily volume and that inside the second set of brackets the conversion of the peak daily volume to the two-way peak volume over a 12-hour operating day.

7.3 Information on Exports by Mode

Statistics Canada publishes an annual report entitled "Exports Merchandise Trade" (cat. 65-202) which contains information on the exports of commodities by transport mode. The published data contain information on the quantity of total exports by commodity group, by province or origin, by county of destination and by mode of transport. Table 7.2 provides an example of the type of information available from this publication for the Province of Ontario. Published data are not available for a finer spatial scale within each Province, although spatially stratified data may be available from Statistics Canada. Area of origin within the Province could be estimated from the commodity type classification.

7.4 Inter-Modal Movements

One of the most rapidly growing methods of shipping long-distance freight to and from Ontario is the combination of truck and rail, particularly piggyback movements. Statistics Canada publishes some very coarse information on weekly railway carloadings in tonnes including separate

TABLE 7.2 Quantity of Total Exports by Commodity Group
and Mode of Transport, Ontario 1980

	Water	Road	Rail	Air	Other
423 Plastics and Synthetic Rubber (100 lbs.)					
	280,768	3,153,425	1,453,479	4,131	-
503 Electric Generators, Motors and Parts (number)					
	1,013	940,378	13,104	18,242	36
621 Pneumatic Tires (number)					
	15,645	2,280,128	780,618	13,418	4,287

Note: in addition exports are stratified by commodity class
for each country of destination for Canada as a whole
but not by Province.

Source: Statistics Canada (1980), "Exports: Merchandise Trade",
Catalogue 65-202.

information for piggyback traffic (Statistics Canada, cat. 11-003E, 52-205). Unfortunately this information is available only for Canada as a whole, or for Eastern and Western Canada, separately. Once again, it may be possible to obtain the information at a spatially stratified scale. However, even in its present form the information does provide control totals that may be used along with more detailed information generated by special surveys.

CHAPTER 8

RECOMMENDED FUTURE STUDIES

8.1 Introduction

The previous chapters have described the principal sources of data that are available on truck movements in Ontario. The data are rather limited with the only data bases being the Statistics Canada annual survey of commodity movements by for-hire trucks and the survey of truck movements on major Ontario highways conducted by the Ontario Ministry of Transportation and Communications in 1978.

This chapter outlines a forecasting procedure that might be used to estimate the annual movement of trucks along the principal inter-city highway corridors in Ontario. The approach outlined in this chapter focusses on truck movements rather than on commodity flows.

8.2 The Forecasting Framework

Figure 8.1 illustrates the major steps of the proposed forecasting procedure. The sequence of activities would be:

- A. A survey of truck origin-destination movements stratified by major commodity group;
- B. Estimation of a log-linear model for each origin-destination matrix in order to establish the interaction structure for each commodity group;
- C. Establish the relationship of truck trip generation and attraction magnitudes for each commodity group to the intermediate and final demand characteristics of each spatial unit;
- D. Estimate the probable interaction structure for the forecast year by modifying the base year interaction matrix to account for potential changes in the economic and spatial structure of Ontario;
- E. Estimate the truck trip generation and attraction magnitudes for each commodity for each spatial unit in the forecast year using the relations established in B and forecasts of economic activity;

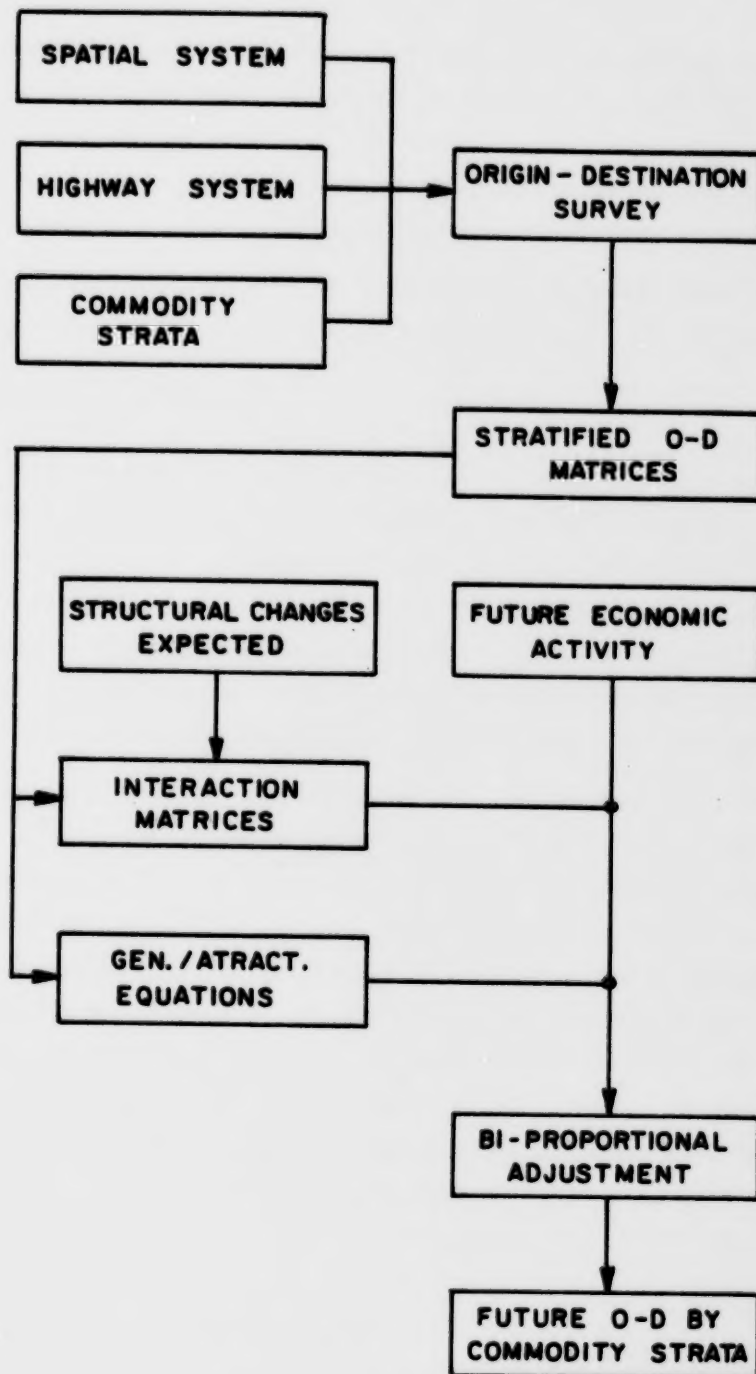


Figure 8.1 - The Forecasting Framework

- F. Adjust the interaction matrix established in D to the new generation and attraction magnitudes estimated in E using bi-proportional balancing procedures, and
- G. Assign the estimated origin-destination magnitudes to the highway network using an all-or-nothing assignment procedure.

The following sections of this chapter describe each of the activities in more detail.

8.3 Spatial System

An MTC Ontario zone system does exist that has been used for the Ontario-Wide Travel Simulation Studies. This is a relatively fine zone system that would be inappropriate for use in any initial studies of Ontario freight movements. Very large samples of truck movements would be required to establish reliable generation and attraction rates as well origin to destination tables. Additionally, there is little systematic and Ontario wide employment data for this zone system.

The most appropriate spatial system to use for the forecasting procedure is the Census Division System established by Statistics Canada. For Southern Ontario this is equivalent to the county/regional municipality system. The principal advantage of this system is that a great deal of census information is available in published form including data derived from the Census of Manufactures and the population census. The number and geographical coverage of each census division is also compatible with the scale of the principal truck movement corridors such as Highways 400, 401, 402, 3 and the QEW. A set of dummy external zones which reflects the major border crossing points would also have to be defined.

8.4 Commodity Groups/Industry Sectors

Most of the information on freight movements that has been collected has been stratified in terms of a commodity classification system, such as the SIC-2 digit code. However, this creates some difficulties as problems are experienced in relating these commodity classifications to

the industrial and consumption structures of the Province. The principal requirement in stratifying freight movement patterns is to allow an updating of these movement markets as the industrial structure and output change. Any classification should attempt to reflect the organization of the production and consumption processes as well as differences in the industrial specialization of different communities in Ontario.

One classification that would better reflect this industry sector emphasis would be:

- A. Natural Resource Movements
 - A.1 Agricultural Products
 - A.2 Forestry Products
 - A.3 Mineral Aggregates
- B. Inter-Industry Movements
 - B.1 Crude Materials, Inedible
 - B.2 Fabricated Materials, Inedible
- C. Movements to Final Demand
 - C.1 Food, Beverages and Tobacco
 - C.2 End Products, Inedible

This classification attempts to stratify in a very coarse way the three major links in the process of production and consumption. While a finer stratification of commodity types would be desirable, the data collection problems would be enormous. These classifications correspond to the six major commodity groups used by Statistics Canada, with the exception that Group V-Motor Vehicles and Parts, has been divided between B.2 and C.2 depending on whether one is dealing with components or end products.

8.5 Origin-Destination Survey

The ultimate objective of the origin-destination survey is to produce origin-destination tables of the annual truck movements within each of the seven commodity movement strata identified previously. An annual time period has been selected since many commodity and production

cycles are long and the forecasting procedure outlined in Section 8.2 envisions relating annual truck movements to annual estimates of economic activity. Shorter term variations in truck movements would have to be derived from annual estimates through empirical observations of shorter term temporal variations.

Very little information is currently available on the temporal variations in trucking movements within each of the commodity movement strata. Reliable sampling and sample expansion procedures can only be established from a sound understanding of the hourly, daily and weekly variations in trucking movements. It will be necessary to build up this information from a series of pilot studies conducted at the truck inspection stations.

It is expected that the permanent traffic counting stations throughout Ontario will gradually be modified to provide information on temporal variations in vehicle movements stratified by vehicle length. While this capability will not be available for one or two years, some initial pilot studies should be conducted at selected truck inspection stations in order to create a quantitative understanding of the temporal variations in truck movements within each of the commodity strata identified previously.

Initial pilot studies could be conducted at the two truck inspection stations located just west of Streetsville on Highway 401. Depending on resources a sequence of daily origin-destination surveys could be conducted over a six month period in order to establish an initial understanding of temporal variations. The survey form developed for the 1978 Commercial Truck Survey should be used in order to provide compatible data bases. Available resources should be concentrated so as to obtain as large a sample as possible on each survey day. These pilot studies could be extended to the other inspection stations in the Toronto-Windsor corridor as resources become available. The principal objective of these pilot studies would be to establish a quantitative understanding of the hourly, daily and weekly variations in truck movements for the seven commodity movement strata identified previously. This information would then provide a basis for the design of more sophisticated sampling schemes.

8.6 Analyses of Survey Data

An eventual origin-destination survey would produce $n \times n$ matrices of trucking movements stratified by the seven commodity classes; or a set of estimated annual truck movements cross-classified by origin, destination and commodity movement stratum. Table 8.1 illustrates the origin-destination table for the Ontario census division system established from the 1978 commercial truck survey. Unfortunately, it is not possible to stratify this table by commodity movement strata.

The first step in the analysis of the origin-destination data is to relate the total truck trips generated and attracted to appropriate independent variables. Section 6.6 has described some generation and attraction equations developed in terms of population. With the stratified tables it would be possible to develop more sophisticated equations since natural resource, inter-industry and final demand related movements would be identified separately. This would allow a wider range of independent variables to be used in developing generation and attraction equations. It should be recalled from Chapter 1 that the Transport Canada analyses established strong statistical associations between annual for-hire truck loadings and manufacturing output, and for-hire truck unloadings and total output.

Interaction characteristics could then be extracted from the origin-destination matrices by fitting a log-linear model of the following form:

$$\ln m_{ij} = u + u_i^A + u_j^B + u_k^C + u_{ij}^{AB} + u_{ik}^{AC} + u_{jk}^{BC} + u_{ijk}^{ABC} \quad (8.1)$$

where the third dimension of the classification scheme, the movement strata, produces another main-effect, two additional two-way interactions and a three-way interaction.

Analysis of the observed data set using the log-linear model defined in equation (8.1) would allow significant effects to be isolated, where the three main effects u_i^A , u_j^B and u_k^C would reflect the impact respectively of zone generation, zone attraction and movement strata. The three interaction terms admit the possibility that the rate of truck

trip making between zones depends on an interaction (of the statistical type) between zone generation size effects and type of movement stratum, as well as between zone attraction size effects and type of movement stratum, and the inter-industry linkages specific to a zonal pair. The three-way interaction term admits the possibility that the rate of truck trip movement between two zones depends on the movement stratum. Analysis of the observed origin-destination data may show that some of the effects defined in equation (8.1) may not be present in the data. If a saturated model is assumed then higher order effects cannot be present if lower order interaction terms are found not to be significant. For example, if u_k^C were found not to be significant then all of the higher order interaction terms containing this main effect could not exist and a two-dimensional log-linear model would result.

A log-linear model has not been fitted to the data in Table 8.1. However, it has been pointed out in Chapter 3 that the pure interaction effects may also be extracted from a flow matrix using bi-proportional balancing techniques. Table 8.2 illustrates the pure zone to zone interaction effects extracted from Table 8.1. The major zone to zone interactions are underlined. If few substantial changes are expected in the interaction structure then the estimates of future truck trip generation and attraction magnitudes developed from the regression equations may be used along with Table 8.2 to produce an estimate of the future truck flow pattern.

If structural changes are expected in the spatial characteristics of the Ontario economy then these may be reflected in the interaction matrix before it is adjusted to the new generation and attraction magnitudes. These adjustments would have to be largely subjective since the macro-economic tools normally used by Provincial agencies do not have a spatial dimension.

Truck trip movements through the Province, such as those moving between Detroit and the Niagara Frontier, will have to be estimated by trend analysis and added to the calculated intra-provincial flows.

TABLE 8.2 Truck Movement Interaction Effects

Greater than 10% of Total after balancing	London	Frank	Lambton	Elgin	Midland	Oxford	Brom	Windsor	Hamilton	Hamilton (North)	Windsor (South)	London	Peel	Metropolitan Toronto	Durham	Toronto	Peterborough	North York	Frontenac	Leeds and Grenville	Strom-Dundas	Ottawa-Carlton	TOTAL	
Keen	0.0651	0.1954	0.0005	0.0503	0.0308	0.0377	-	0.0322	0.1104	0.0117	0.0360	0.0559	0.0833	0.0388	0.0194	0.0041	0.0170	0.0519	0.0043	-	-	0.0045	1.0001	
Keen	0.1254	0.1791	0.0037	0.0108	0.0047	0.0055	0.0495	-	0.0131	0.0736	0.0081	-	0.0197	0.0058	0.0194	0.0049	-	-	-	-	-	0.0138	1.0001	
Lambton	0.1011	0.0089	0.1374	0.0407	0.0065	0.0229	0.0495	0.0565	0.1072	0.0107	0.0172	-	0.0165	0.0218	0.0184	0.0330	-	0.0044	0.0098	0.0187	0.0318	0.1249	1.0003	
Elgin	0.0053	-	0.0501	0.1354	0.0474	0.0545	0.0884	0.0567	0.0981	0.0432	-	-	0.0353	0.0449	0.0345	0.0294	-	0.0711	-	0.0833	0.0284	-	1.0000	
Midland	0.0971	0.0219	0.1414	0.0987	0.0437	0.0903	0.1070	0.0655	0.0990	0.0410	0.0329	0.0150	0.0134	0.0188	0.0234	0.0182	-	0.0401	0.0792	0.0102	-	0.0377	0.9997	
Oxford	0.0991	0.0438	0.0770	0.0649	0.0377	0.0902	-	-	-	0.0417	0.0210	-	-	0.0474	0.0408	0.0848	-	0.1967	0.1246	0.0461	-	-	0.9998	
Brom	-	0.0239	-	-	0.0212	-	0.1777	-	-	-	-	-	-	0.0387	0.0589	0.0444	0.2710	0.2284	0.1208	0.0147	-	-	0.9997	
Windsor	0.0754	0.0230	0.0767	0.0234	0.0712	0.0177	-	0.1371	-	0.0115	0.0412	0.0220	0.0128	0.0818	0.0803	0.0818	0.0651	0.0634	0.0877	0.0501	-	0.9999		
Hamilton	0.0600	0.0135	0.1220	0.0274	0.0894	-	-	-	-	0.0108	0.0922	0.0248	0.0699	0.0218	0.0734	0.0042	0.2544	-	0.0377	0.0944	-	-	1.0000	
Hamilton-North	0.0403	0.0402	0.0517	0.0272	0.0163	-	0.0134	0.0130	-	0.0697	0.0229	0.0321	0.0745	0.0578	0.0789	0.0373	0.0759	0.0434	0.0877	0.1454	0.0200	0.0398	1.0000	
Windsor (North)	0.0907	-	0.0523	0.0356	0.0225	0.0322	0.0491	0.0477	0.1385	0.1031	0.0477	0.0475	0.0755	0.0444	0.0626	0.0727	-	0.0312	0.0718	0.0548	-	0.0155	1.0001	
Windsor (South)	0.0103	-	0.0487	0.0277	0.0283	0.0240	0.0216	0.0049	0.1136	0.1004	0.1016	0.1106	0.0857	-	0.0785	0.0250	-	0.0576	0.0500	0.0647	-	0.0346	0.9999	
Peel	0.0272	-	0.0126	0.0973	0.0493	0.0111	0.0216	0.0049	0.0771	0.0608	0.1010	0.0390	0.2264	0.0434	0.0575	0.0495	0.1878	0.0145	0.0352	-	0.0208	-	0.9997	
Metropolitan Toronto	0.0365	0.0113	0.0279	0.0270	0.0489	0.0287	0.0743	0.0603	0.0544	0.0944	0.0546	0.0816	0.0213	0.1832	0.0705	0.0411	0.0322	0.0104	-	-	0.0202	0.0654	1.0000	
North York	0.0447	0.0670	0.0415	0.0892	0.0251	0.0531	-	0.0408	0.0644	0.0537	0.0628	0.0398	0.0612	0.0028	0.0179	0.0926	0.0975	0.0103	0.0223	0.0434	0.0615	0.0095	0.9999	
Victoria	-	-	-	-	0.1122	0.2921	-	0.2020	-	-	-	0.2432	-	-	-	0.0486	-	-	-	-	-	-	0.9997	
Peterborough	-	0.0319	0.0363	0.0526	0.0177	0.0332	0.0941	0.0771	0.1271	0.0777	0.0984	0.0124	-	0.0454	0.0435	0.1379	-	0.0515	-	-	0.0154	-	1.0002	
Windsor	0.0563	-	-	-	0.0395	0.0699	0.0902	0.0321	-	0.0150	0.0740	0.0558	0.1004	0.0315	0.0555	0.0428	-	-	0.0563	-	0.0917	-	1.0001	
Frontenac	-	-	-	-	0.1161	0.0699	-	0.0687	-	0.0515	-	0.0639	0.0499	0.0315	0.0540	0.0697	-	0.0607	0.2489	0.0819	0.1689	0.1608	0.0728	1.0001
Leeds and Grenville	-	0.0168	0.0079	-	-	-	0.1463	0.0234	0.1109	0.0137	0.0213	0.0534	0.0041	-	0.0144	0.0087	-	0.0098	0.0570	0.0947	0.3115	-	1.0004	
Strom-Dundas	0.0082	0.0230	0.0129	-	0.0565	0.0095	-	0.0817	0.2423	0.0187	0.0254	0.0175	0.0104	0.0050	0.0319	0.0142	-	0.0092	-	0.1019	0.0658	0.2316	0.0458	1.0005
Ottawa-Carlton	0.0098	0.0081	0.0099	1.0001	1.0001	0.9999	1.0000	1.0002	0.9998	1.0000	1.0000	1.0001	1.0002	1.0002	1.0000	1.0001	1.0000	0.9999	1.0003	1.0000	1.0001	0.9999	1.0000	

CHAPTER 9

CONCLUSIONS AND RECOMMENDATIONS

The broad aims of the research project described in this report were to explore alternative methods for estimating truck volumes on the provincial highway network and to examine the utility of available data bases for the calibration of the selected forecasting framework. This chapter summarizes the principal conclusions developed during the study and outlines recommendations for future work in this area.

9.1 Conclusions

Future Role of Trucking

A review of some recent federal government studies suggests that commodity tonnes shipped by for-hire trucks within Ontario are likely to grow at about 3.4 percent per year throughout the 1980s. Trucking is expected to continue as the dominant transport mode used for intra-provincial freight shipments, except for the movement of crude materials.

Forecasting Method

The most appropriate method for forecasting future truck volumes along the principal corridors of the provincial highway system is a growth factor approach. This approach represents a balance between scientific integrity and data needs.

The growth factor method requires two major steps. First, truck trip generation and attraction magnitudes have to be related to causal variables reflecting production and consumption. Second, a log-linear model has to be estimated from observed origin-destination flows allowing the zone to zone inter-industry commodity flow linkages to be isolated. Forecasts of economic activity by zone are then used to estimate future truck trip generation and attractions. The inter-

action terms of the log-linear model are then used along with these estimated generations and attractions to forecast future origin-destination volumes using bi-proportional adjustment techniques.

Statistics Canada For-Hire Trucking Data

The Statistics Canada annual survey of commodity shipments by for-hire trucks yields estimates of the annual tonnes of commodities in each of six commodity groups shipped between the ten major population centres of Ontario.

Regression analyses of the commodity generation and attraction rates provided very broad statistical associations with variables such as manufacturing man-hours and population. Since the data are coded to only ten zones the number of independent effects that could be incorporated into the regression equations was severely restricted.

Bi-proportional reductions of the inter-zonal commodity flow data provided some understanding of the inter-industry linkages in Ontario. The coarse spatial scale to which the data are coded and the modest statistical reliability of the data base restricted the generality of these analyses.

It has been concluded that the Statistics Canada for-hire trucking survey data is inappropriate for use in truck movement studies.

MTC Commercial Vehicle Survey

The 1978 MTC Commercial Vehicle Survey provides a more reliable and direct estimate of truck flows between some 35 cities and towns in Ontario.

Statistically valid prediction equations for truck trip generations and attractions with high explanatory powers have been developed in terms of the population of each community. Significant over- and under-estimation residuals exist for some communities and these residuals reflect variations in the employment composition of the communities. Communities containing motor vehicle assembly plants generated and attracted truck trips at a much higher than average rate. Communities with employment concentrations in the office sector generated and attracted truck trips

at a much lower than average rate. More sophisticated prediction equations could have been developed if truck movement data stratified by commodity group were available along with reliable data on employment composition.

Bi-proportional reductions of the truck flow data revealed a very different inter-city interaction structure than that derived from the Statistics Canada data. The destination probability vectors of the eight major population centres of Ontario derived from the MTC survey are more homogeneous both for for-hire and private trucks than those obtained from the Statistics Canada survey. This greater homogeneity reflects no doubt the larger sample size and the focus of the survey on truck movements rather than commodity movements. A more sophisticated analysis of the interaction structure would have been possible if origin-destination trip tables stratified by major commodity group were available from the 1979 survey.

9.2 Recommendations

The census division spatial system used by Statistics Canada should be used as the basic spatial system for the forecasting framework. A great deal of demographic and economic information is available for this spatial system on a routine basis.

The forecasting procedure should be developed in terms of annual truck movements with empirical observations of seasonal, daily and hourly variations being used to convert the annual flows to flows over shorter-time periods.

Truck movements should be measured and forecast in terms of seven broad commodity groups which reflect the principal stages of the production and consumption process: natural resource movements, inter-industry movements, and movements to final demand.

The data required to implement this approach should be obtained using a two-stage survey. An initial pilot study should be conducted at selected truck inspection stations in order to establish the temporal variation of truck movements by the principal commodity movement groups. This information is essential in order to establish a reliable sampling scheme. An appropriate sampling and expansion procedure could then be

established in order to estimate reliable origin-destination matrices for each of the major commodity groups.

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APPENDIX A

STATISTICS CANADA FOR-HIRE TRUCKING SURVEY DATA

Statistics Canada has conducted an annual survey of for-hire trucking since 1973. The objectives of this survey are to provide reliable estimates concerning the origin and destination of domestic inter-city (defined as over 24.1 km) commodity movements by for-hire motor carriers. The information normally published from this survey for each major population centre in Canada are revenues, tonnes shipped and tonne-kilometres moved.

The universe for the survey consists of those carriers whose reports to the Statistics Canada Motor Carriers-Freight and Household Goods Movers Survey for the previous year showed earnings of \$100,000 or more from the domestic movement of goods over more than 24.1 km on public roads.

A sample of companies is then established across Canada and interviewers visit each company and establish the aggregate operating characteristics of the firm and sample individual shipments. The items recorded for the shipment include origin, destination, type of merchandise, weight and transport revenue carried.

Trucking activities that are excluded from the survey universe include: (i) courier/parcel delivery services, (ii) rail and air express companies except CP Express, (iii) construction, logging excavation and mineral aggregate companies, (iv) truck rental firms, (v) carriers domiciled out of Canada, and (vi) private trucking firms. In addition, international shipments and shipments transported 15 miles or less are excluded.

The sample design is a two-stage, twice replicated, probability proportional to size, systematic sample of 225,000 shipments drawn from an estimated (in 1979) 32.7 million inter-city shipping records. The sampling points are stratified according to: (1) area

of province of operation, (ii) type of trucking activity, and (iii) size of carrier or terminal measured in terms of revenues in units of \$10,000.

In 1979 the allocation of the sample to an individual stratum was done in two steps and these were: (i) allocation by revenue size : 90,800 shipments from carriers with revenues \$2 million or more : 82,000 shipments from carriers with revenues of (0.5 to \$2 million, and the remainder to the smaller carriers; and (ii) allocation by stratum where the allocation of sampling within groups is proportional to the stratum size. The sampling process was repeated in order to obtain two independent sets of samples.

The coefficient of variation (standard deviation divided average) has been estimated for the tonnes attracted and the tonnes generated and these are presented in Tables A.1 and A.2, respectively for the population centres analyzed in the report. The tables show that, in general, the coefficient of variation increases with the decreasing volume of shipments. The large coefficients of variation tend to explain some of the large year to year variations observed in the commodity attractions and generations presented in Chapter 4.

Table A.3 contains information on the estimated inter-city commodity shipments between the eleven Canadian population centres that have the major impacts on truck movements in Ontario.

Table A.1 Coefficients of Variation for For-Hire
Trucking Tonnes Attracted

	1973	1974	1975	1976	1977	1978	1979
Ottawa-Hull	B	A	A	B	C	B	A
Oshawa	-	-	-	A	C	A	A
Toronto	A	A	B	B	A	A	A
Hamilton	B	B	C	B	B	B	B
St. Cath.-N.F.	A	C	D	B	B	A	A
Kitchener	A	C	A	A	B	A	D
London	C	A	B	A	A	A	A
Windsor	B	C	C	C	B	A	C
Sudbury	C	B	C	A	D	A	A
Thunder Bay	E	C	A	B	C	A	A
Montreal	A	A	B	B	A	B	A

A = 0.0 - 9.9
B = 10.0 - 19.9
C = 20.0 - 29.9
D = 30.0 - 49.9
E = 50.0 or more

TABLE A.2 Coefficients of Variation for For-Hire
Trucking Tonnes Generated

	1973	1974	1975	1976	1977	1978	1979
Ottawa-Hull	C	A	D	B	B	C	A
Oshawa	-	-	-	B	A	A	B
Toronto	A	A	A	B	A	A	A
Hamilton	A	B	A	A	B	A	A
St. Cath.-N.F.	B	A	A	A	C	A	B
Kitchener	A	A	B	C	A	A	B
London	D	C	D	A	B	C	D
Windsor	B	C	C	B	A	D	B
Sudbury	D	B	E	A	E	B	B
Thunder Bay	E	C	A	E	E	D	E
Montreal	A	A	B	C	A	A	A

A = 0.0 - 9.9
B = 10.0 - 19.9
C = 20.0 - 29.9
D = 30.0 - 49.9
E = 50.0 or more

TABLE A.3 Statistics Canada For-Hire Trucking Commodity Movements, 1979

ORIGIN	DESTINATION	GRP	RECORD COUNT	ESTIMATED SHIPMENT	ESTIMATED REVENUE	ESTIMATED TONNES	ESTIMATED TONNES-KM
MONTREAL	MONTREAL	2	68	3,444	1,099,288	80,204	5,559,732
		3	9	798	131,188	12,821	507,376
		4	209	14,564	2,444,604	231,825	10,817,738
		5	457	49,948	5,096,813	184,103	13,678,861
		6	74	21,024	513,125	13,235	908,591
TOTAL FOR DESTINATION	.....		817	89,781	9,285,018	522,188	31,472,298
	OTTAWA HULL	2	95	12,414	2,011,309	77,963	18,115,936
		3	1	25	24,724	1,029	200,241
		4	204	20,964	3,402,571	203,222	43,747,977
		5	340	53,173	5,697,224	167,269	40,654,408
		6	174	34,707	1,847,392	39,065	8,081,632
TOTAL FOR DESTINATION	.....		814	121,285	13,063,220	488,548	110,800,194
	OSHAWA	2	4	243	114,407	3,391	2,076,377
		4	10	691	194,851	10,150	5,511,460
		5	17	2,356	338,447	4,980	2,753,385
		6	10	6,240	91,464	533	305,492
TOTAL FOR DESTINATION	.....		41	9,531	739,169	19,054	10,646,714
	TORONTO	1	21	219	205,359	17,257	9,914,587
		2	180	11,640	6,402,058	202,571	113,642,898
		3	6	1,342	293,509	2,860	1,706,090
		4	366	42,077	10,325,869	220,866	126,500,637
		5	673	79,378	15,122,881	170,008	96,944,924
		6	116	32,154	3,713,490	50,454	28,216,428
TOTAL FOR DESTINATION	.....		1,362	166,813	36,063,166	664,016	376,925,564
	HAMILTON	2	9	677	320,253	4,401	2,812,837
		3	1	15	90,032	5,079	3,106,274
		4	44	5,141	2,580,699	76,369	47,666,419
		5	73	7,582	1,483,652	18,560	11,461,620
		6	14	10,129	717,155	6,272	3,847,490
TOTAL FOR DESTINATION	.....		141	23,546	5,191,791	110,681	68,894,640
	ST CATHERINES NIAGRA	2	2	100	136,329	3,362	2,029,135
		4	26	2,698	1,179,032	33,853	21,899,871
		5	31	5,788	746,120	3,509	2,311,624
		6	8	4,350	102,496	507	340,751
TOTAL FOR DESTINATION			67	12,936	2,163,977	41,311	26,581,381
	KITCHENER	2	13	669	523,254	15,030	10,317,454
		3	3	292	228,597	4,177	2,756,135

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ORIGIN	DESTINATION	GRP	RECORD COUNT	ESTIMATED SHIPMENT	ESTIMATED REVENUE	ESTIMATED TONNES	ESTIMATED TONNES-KM
MONTREAL	KITCHENER	4	44	6,528	845,723	15,218	10,002,530
		5	57	13,534	817,796	4,224	2,820,933
		6	18	7,423	364,160	3,244	2,137,821
TOTAL FOR DESTINATION	.....		135	28,449	2,779,530	41,893	28,034,873
	LONDON	2	19	1,044	723,330	20,734	15,180,881
		3	1	227	3,510	5	3,989
		4	28	5,831	929,566	11,578	8,682,337
		5	66	8,900	1,379,428	9,619	7,112,052
		6	10	3,159	216,491	2,868	2,096,632
TOTAL FOR DESTINATION	.....		124	19,213	3,252,325	44,804	33,075,891
	WINDSOR	2	4	303	76,994	341	321,011
		3	1	106	11,465	44	40,802
		4	11	1,160	762,204	20,021	19,050,449
		5	36	3,364	863,788	6,698	6,875,772
		6	4	2,337	33,363	107	97,904
TOTAL FOR DESTINATION	.....		56	7,272	1,747,814	27,211	26,385,938
	SUREY	2	2	275	219,141	4,916	3,450,024
		4	14	1,672	634,641	6,367	4,830,822
		5	58	8,180	747,974	11,782	8,300,727
		6	6	2,355	41,103	260	183,921
TOTAL FOR DESTINATION	.....		80	12,483	1,642,859	23,325	16,765,494
	THUNDER BAY	2	2	225	32,842	128	208,472
		4	8	1,202	892,402	8,184	13,068,192
		5	14	1,562	306,945	2,050	3,592,572
		6	1	119	4,224	8	12,426
TOTAL FOR DESTINATION	.....		25	3,110	1,236,413	10,370	16,881,662
TOTAL FOR ORIGIN	.....		3,662	494,423	77,165,282	1,993,401	746,464,649
OTTAWA HULL	MONTREAL	2	13	1,492	313,489	19,838	6,028,979
		3	1	130	119,928	5,171	1,006,912
		4	131	8,676	2,912,497	198,514	47,093,937
		5	126	16,485	2,095,363	38,698	8,186,845
		6	94	8,153	443,660	8,913	1,750,317
TOTAL FOR DESTINATION	.....		365	34,938	5,884,937	271,134	64,071,990
	OTTAWA HULL	2	2	165	32,555	1,123	30,717
		3	4	42	31,829	11,110	465,603
		4	23	663	146,687	23,588	954,759
		5	2	49	1,271	340	9,313

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ORIGIN	DESTINATION	GRP	RECORD COUNT	ESTIMATED SHIPMENT	ESTIMATED REVENUE	ESTIMATED TONNES	ESTIMATED TONNES-KM
TOTAL FOR DESTINATION	.....		31	920	212,342	36,101	1,460,392
OTTAWA HULL	OSHAWA	5	3	208	43,919	159	57,613
		6	1	55	6,224	30	10,202
TOTAL FOR DESTINATION	.....		4	263	50,143	189	67,815
	TORONTO	2	8	862	474,988	10,836	4,317,163
		4	41	4,066	1,274,897	70,232	29,049,350
		5	148	19,546	2,008,233	35,899	14,973,564
		6	67	7,648	335,776	3,454	1,376,961
TOTAL FOR DESTINATION	.....		264	32,123	4,093,894	120,421	49,719,238
	HAMILTON	3	2	44	37,486	1,854	859,714
		4	4	392	149,963	6,802	3,106,829
		5	9	716	220,023	713	324,497
TOTAL FOR DESTINATION	.....		15	1,153	407,472	9,369	4,291,040
	ST CATHERINES NIAGRA	2	1	68	70,775	989	518,982
		4	2	122	26,889	1,865	944,425
		5	2	120	25,017	60	30,584
		6	4	218	28,806	126	64,497
TOTAL FOR DESTINATION	.....		9	529	151,487	3,040	1,558,488
	KITCHENER	5	9	2,529	378,975	8,596	4,402,129
		6	1	498	12,148	19	9,423
TOTAL FOR DESTINATION	.....		10	3,028	391,123	8,615	4,411,552
	LONDON	4	2	316	51,168	912	528,415
		5	6	677	86,846	432	249,911
		6	7	384	68,180	475	275,401
TOTAL FOR DESTINATION	.....		15	1,377	206,194	1,819	1,053,727
	WINDSOR	4	10	252	430,635	14,466	10,965,691
		5	4	274	220,096	2,724	2,065,217
TOTAL FOR DESTINATION	.....		14	527	650,731	17,190	13,030,908
	SUREY	4	5	519	190,442	4,818	2,802,119
		5	5	599	66,334	263	139,374
		6	27	1,968	182,980	2,065	1,031,171
TOTAL FOR DESTINATION			37	3,087	419,756	7,151	3,972,664

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ORIGIN	DESTINATION	GRP	RECORD COUNT	ESTIMATED SHIPMENT	ESTIMATED REVENUE	ESTIMATED TONNES	ESTIMATED TONNES-KM
OTTAWA HULL	THUNDER BAY	5	1	13	64,211	132	192,138
TOTAL FOR DESTINATION	.....		1	13	64,211	132	192,138
TOTAL FOR ORIGIN	.....		765	77,962	12,532,290	475,161	143,829,952
OSHAWA	MONTREAL	2	1	50	1,633	3	1,596
		4	61	1,159	855,085	37,614	22,967,509
		5	104	19,983	3,897,951	71,000	39,568,115
		6	2	237	12,828	32	17,452
TOTAL FOR DESTINATION	.....		168	21,459	4,767,497	108,649	6,555,072
OTTAWA HULL		2	2	509	117,488	4,272	1,649,893
		4	4	1,289	55,683	620	239,658
		5	16	6,620	981,155	25,083	8,703,808
TOTAL FOR DESTINATION	.....		22	8,419	1,154,326	29,975	10,593,359
TORONTO		2	9	885	203,759	7,937	368,936
		3	7	553	159,270	21,786	1,157,419
		4	22	2,392	309,217	33,345	1,735,708
		5	305	32,547	2,617,268	125,717	6,690,945
		6	3	735	23,762	377	20,071
TOTAL FOR DESTINATION	.....		346	37,114	3,313,276	189,162	9,973,079
HAMILTON		3	1	46	21,204	3,277	390,261
		4	9	1,154	433,911	45,667	5,132,776
		5	54	8,009	380,914	21,150	2,472,768
TOTAL FOR DESTINATION	.....		64	9,210	836,029	70,094	7,995,605
ST CATHERINES NIAGRA		2	2	436	237,775	16,130	1,531,549
		4	2	3,199	248,254	21,797	2,421,379
		5	8	5,429	442,439	15,924	2,582,752
TOTAL FOR DESTINATION	.....		12	9,065	928,468	53,851	6,535,680
KITCHENER		2	9	839	354,009	34,935	5,293,076
		3	2	168	18,723	297	45,433
		4	2	112	4,589	32	4,797
		5	17	5,660	807,276	18,667	2,845,277
		6	2	991	14,758	12	1,833
TOTAL FOR DESTINATION			32	7,792	1,199,355	53,943	8,190,416
LONDON		5	15	3,803	242,629	3,568	832,713
		6	1	227	12,635	103	25,314

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ORIGIN	DESTINATION	GRP	RECORD COUNT	ESTIMATED SHIPMENT	ESTIMATED REVENUE	ESTIMATED TONNES	ESTIMATED TONNES-KM
TOTAL FOR DESTINATION	.....		16	4,030	255,264	3,671	858,027
OSHAWA	WINDSOR	4	2	391	63,398	744	319,445
		5	25	4,657	772,566	20,077	8,646,203
TOTAL FOR DESTINATION	.....		27	5,048	835,964	20,821	8,965,648
	SUBURY	3	1	155	11,912	40	15,397
		5	3	819	109,098	1,586	603,644
TOTAL FOR DESTINATION	.....		4	974	121,010	1,626	624,041
	THUNDER BAY	5	2	25	31,140	51	66,958
TOTAL FOR DESTINATION	.....		2	25	31,140	51	66,958
TOTAL FOR ORIGIN	.....		693	103,142	13,442,329	531,843	116,358,085
TORONTO	MONTREAL	1	5	105	47,099	1,342	757,266
		2	170	10,367	5,443,761	156,030	88,261,125
		3	14	2,679	1,925,056	20,061	11,288,197
		4	413	44,025	11,135,377	241,261	138,452,822
		5	951	130,684	23,309,776	299,303	168,652,200
		6	248	50,164	7,770,891	157,317	87,559,307
TOTAL FOR DESTINATION	.....		1,801	238,027	49,681,962	875,314	494,970,917
	OTTAWA HULL	2	213	18,286	4,491,450	124,043	50,918,734
		3	9	752	209,064	5,672	2,497,582
		4	162	25,929	3,491,963	124,040	52,525,356
		5	421	95,178	9,039,194	107,259	43,158,236
		6	144	36,913	1,821,067	29,593	12,050,580
TOTAL FOR DESTINATION	.....		949	177,060	19,052,738	390,607	161,150,488
	OSHAWA	2	34	2,022	375,275	23,157	1,217,971
		3	42	2,728	467,663	183,064	6,888,216
		4	122	10,706	1,070,598	132,459	8,286,401
		5	246	24,233	2,307,999	87,705	5,928,027
		6	14	3,179	191,009	10,992	545,069
TOTAL FOR DESTINATION	.....		458	42,871	4,432,544	437,377	22,865,684
	TORONTO	1	5	162	31,306	4,599	148,224
		2	132	13,512	2,087,726	110,024	5,005,377
		3	697	108,338	7,938,512	4,566,387	126,585,599
		4	820	110,563	13,611,148	2,604,309	115,984,022
		5	808	156,859	8,995,977	274,740	12,667,946
		6	102	29,447	1,435,637	90,653	3,678,803

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ORIGIN	DESTINATION	GRP	RECORD COUNT	ESTIMATED SHIPMENT	ESTIMATED REVENUE	ESTIMATED TONNES	ESTIMATED TONNES-KM
TOTAL FOR DESTINATION	.....		2,564	418,893	34,100,306	7,650,912	328,069,971
TORONTO	HAMILTON	1	176	4,803	1,376,496	201,696	11,362,736
		2	106	12,927	1,213,134	72,670	4,670,165
		3	145	8,004	1,809,233	470,473	38,462,148
		4	436	40,491	5,491,500	706,216	35,094,721
		5	526	121,853	4,977,421	145,195	8,450,250
		6	55	21,578	846,094	24,907	1,421,599
TOTAL FOR DESTINATION	.....		1,444	209,659	15,713,878	1,621,157	99,461,618
	ST CATHERINES NIAGRA	2	73	6,247	1,083,006	64,089	6,536,992
		3	31	3,061	581,821	62,937	6,273,024
		4	165	15,328	2,524,760	282,938	23,796,433
		5	289	62,191	3,935,095	226,366	26,439,691
		6	65	18,334	980,952	29,205	2,942,846
TOTAL FOR DESTINATION	.....		623	107,162	9,105,634	665,535	65,990,986
	KITCHENER	1	12	327	144,396	13,752	1,505,208
		2	131	20,470	3,477,528	206,121	21,762,571
		3	32	2,229	383,051	27,196	2,290,679
		4	204	31,164	3,152,050	423,702	35,483,935
		5	348	86,852	6,214,529	224,537	23,236,469
		6	33	17,194	464,699	10,621	1,219,173
TOTAL FOR DESTINATION	.....		765	158,239	13,836,253	905,929	85,498,035
	LONDON	2	162	11,990	3,921,366	159,094	28,660,542
		3	5	465	41,177	2,896	463,060
		4	193	22,500	2,647,827	101,765	18,475,881
		5	388	120,772	5,366,488	83,918	15,066,590
		6	131	17,385	1,707,094	66,692	11,833,942
TOTAL FOR DESTINATION	.....		879	173,112	13,683,952	414,365	74,500,015
	WINDSOR	1	1	168	13,597	84	29,966
		2	127	10,119	2,570,161	125,221	46,162,039
		3	8	483	169,701	12,932	4,831,708
		4	117	12,483	2,300,477	82,450	30,110,147
		5	266	40,257	4,876,959	95,330	34,082,147
		6	74	2,622	1,224,491	41,188	14,767,186
TOTAL FOR DESTINATION	.....		593	66,135	11,155,376	357,205	129,983,193
	SUBURY	2	143	8,966	1,919,954	44,772	18,333,243
		3	5	563	99,481	2,822	1,156,072
		4	96	10,184	1,869,697	63,852	30,863,246
		5	220	34,019	2,446,277	22,635	10,378,421

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ORIGIN	DESTINATION	GRP	RECORD COUNT	ESTIMATED SHIPMENT	ESTIMATED REVENUE	ESTIMATED TONNES	ESTIMATED TONNES-KM
TORONTO	SUBURY	6	110	11,033	1,834,648	55,400	22,789,089
TOTAL FOR DESTINATION	.....		574	64,767	8,170,057	189,481	83,520,071
	THUNDER BAY	2	29	1,682	1,186,889	15,592	21,946,922
		3	1	158	7,353	28	39,546
		4	73	4,565	3,172,514	60,369	84,602,366
		5	73	8,379	1,583,556	9,644	13,582,621
		6	20	3,079	697,608	9,567	15,470,378
TOTAL FOR DESTINATION	.....		196	17,865	6,652,920	95,200	133,641,833
TOTAL FOR ORIGIN	.....		10,846	1,673,795	185,585,620	13,603,082	1,679,652,811
HAMILTON	MONTREAL	2	10	1,112	448,300	7,029	4,333,099
		3	2	27	41,686	1,979	1,217,541
		4	86	7,865	6,167,316	273,945	185,101,966
		5	44	5,154	2,157,565	33,793	24,238,595
		6	8	1,288	251,134	3,243	1,984,740
TOTAL FOR DESTINATION	.....		150	15,449	9,066,001	319,989	216,875,931
	OTTAWA HULL	2	12	1,280	419,148	10,536	4,906,652
		3	1	46	39,973	694	362,686
		4	6	578	133,937	1,781	825,479
		5	22	3,436	779,344	10,598	4,903,557
		6	11	2,166	175,801	1,957	889,934
TOTAL FOR DESTINATION	.....		52	7,507	1,548,203	25,556	11,688,508
	OSHANA	2	1	119	6,961	50	5,879
		3	6	359	66,715	7,282	855,730
		4	31	3,771	956,706	133,955	15,931,464
		5	12	1,146	188,147	13,864	1,507,410
		6	1	119	3,047	26	3,164
TOTAL FOR DESTINATION	.....		51	5,516	1,221,576	155,177	18,303,655
	TORONTO	2	38	5,360	831,544	39,451	2,762,852
		3	159	12,457	1,820,326	665,749	35,915,761
		4	467	39,006	10,230,620	1,677,666	109,363,264
		5	260	33,965	3,211,539	140,142	8,298,611
		6	26	3,626	208,980	12,239	743,850
TOTAL FOR DESTINATION	.....		950	94,417	16,303,009	2,535,247	157,084,338
	HAMILTON	3	2	424	70,821	21,065	644,118
TOTAL FOR DESTINATION			2	424	70,821	21,065	644,118

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ORIGIN	DESTINATION	GRP	RECORD COUNT	ESTIMATED SHIPMENT	ESTIMATED REVENUE	ESTIMATED TONNES	ESTIMATED TONNES-KM
HAMILTON	ST CATHERINES NIAGRA	2	2	325	15,143	96	5,646
		3	28	1,214	270,116	60,959	3,439,738
		4	162	13,675	3,658,342	759,499	49,609,100
		5	40	3,268	450,944	26,343	1,654,744
		6	1	73	14,867	1,604	113,549
TOTAL FOR DESTINATION	.....		233	18,556	4,409,412	848,511	54,822,777
	KITCHENER	2	5	1,970	682,256	36,966	2,451,274
		3	1	188	29,709	565	26,389
		4	51	6,344	1,783,985	211,473	11,921,813
		5	23	6,089	604,112	56,675	3,544,031
		6	4	1,683	65,104	388	23,904
TOTAL FOR DESTINATION	.....		84	16,275	3,165,166	306,067	17,967,411
	LONDON	2	8	286	99,865	8,106	1,225,555
		4	28	2,939	578,276	58,902	7,861,605
		5	36	5,521	562,372	9,395	1,280,526
TOTAL FOR DESTINATION	.....		72	8,747	1,240,513	76,403	10,367,686
	WINDSOR	2	3	3,300	90,042	500	152,465
		3	3	127	77,626	10,963	3,334,593
		4	65	3,805	1,999,949	171,696	54,003,136
		5	24	1,843	449,746	13,886	4,595,190
		6	2	7	528	6	1,930
TOTAL FOR DESTINATION	.....		99	9,085	2,617,891	197,051	62,087,314
	SUBURY	2	4	362	224,464	3,636	1,629,386
		4	23	851	297,299	21,140	10,832,814
		5	7	846	264,595	4,940	2,172,673
		6	1	155	2,345	1	420
TOTAL FOR DESTINATION	.....		35	2,215	788,703	29,717	14,635,293
	THUNDER BAY	2	2	205	124,582	3,015	4,388,304
		4	5	274	227,908	6,607	9,625,565
		5	14	1,807	298,631	2,478	3,604,289
		6	1	129	327,417	2,046	2,979,853
TOTAL FOR DESTINATION	.....		22	2,416	976,539	14,146	20,598,031
TOTAL FOR ORIGIN	.....		1,750	180,611	41,407,833	4,529,929	585,275,062
ST CATHERINES NIAGRA	MONTREAL	2	6	274	373,819	11,552	7,268,014
		3	2	54	131,696	2,789	1,707,287
		4	152	3,632	2,012,760	39,852	27,191,141
		5	32	2,977	1,636,190	21,793	13,849,031

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ORIGIN	DESTINATION	GRP	RECORD COUNT	ESTIMATED SHIPMENT	ESTIMATED REVENUE	ESTIMATED TONNES	ESTIMATED TONNES-KM
ST CATHERINES NIAGRA	MONTREAL	6	3	516	74,973	356	239,253
TOTAL FOR DESTINATION	.....		195	7,456	4,229,458	76,342	50,254,726
	OTTAWA HULL						
		2	2	173	125,955	1,601	812,028
		4	2	125	35,833	1,044	469,698
		5	5	980	155,696	1,892	825,304
		6	2	433	67,668	1,515	636,752
TOTAL FOR DESTINATION	.....		11	1,712	385,352	6,052	2,743,782
	OSHAWA						
		4	16	806	321,073	27,579	2,874,432
		5	26	5,880	2,511,626	189,438	30,682,508
		6	1	218	41,140	299	30,802
TOTAL FOR DESTINATION	.....		43	6,905	2,873,839	217,316	33,587,742
	TORONTO						
		1	1	23	16,607	1,158	152,928
		2	51	3,547	1,317,315	113,206	13,349,623
		3	19	789	297,272	22,328	1,994,088
		4	106	10,690	2,583,872	214,774	22,485,769
		5	132	12,348	2,232,029	97,896	9,566,956
		6	11	646	124,118	11,610	1,332,849
TOTAL FOR DESTINATION	.....		320	28,045	6,551,213	460,972	48,882,213
	HAMILTON						
		2	16	1,121	556,245	47,437	3,330,032
		3	9	399	118,397	23,858	1,393,105
		4	46	4,199	1,047,608	150,334	10,590,843
		5	21	1,660	299,497	26,717	1,751,626
		6	2	73	29,986	2,920	159,786
TOTAL FOR DESTINATION	.....		94	7,454	2,051,933	250,866	17,225,442
	ST CATHERINES NIAGRA						
		2	53	1,979	695,946	69,270	2,626,138
		4	20	1,700	518,475	55,503	1,525,639
		5	8	588	98,593	22,230	643,952
TOTAL FOR DESTINATION	.....		81	4,268	1,313,019	147,003	4,795,729
	KITCHENER						
		2	8	930	101,108	2,593	330,943
		3	4	121	48,918	6,689	866,705
		4	10	1,293	297,283	14,999	2,010,639
		5	6	1,225	181,858	4,845	633,475
TOTAL FOR DESTINATION			28	3,571	629,167	29,126	3,841,841
	LONDON						
		2	5	400	111,450	5,832	1,094,475
		3	6	225	134,312	12,292	2,393,599

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ORIGIN	DESTINATION	GRP	RECORD COUNT	ESTIMATED SHIPMENT	ESTIMATED REVENUE	ESTIMATED TONNES	ESTIMATED TONNES-KH
ST CATHERINES NIAGRA	LONDON	4	12	329	210,657	19,527	4,046,833
		5	6	655	97,960	721	141,939
		6	3	682	36,353	144	27,901
TOTAL FOR DESTINATION	.....		32	2,793	590,732	38,516	7,704,797
	WINDSOR	2	5	647	102,979	3,607	4,323,505
		3	1	128	3,686	29	10,315
		4	7	720	398,303	22,084	6,048,410
		5	5	735	447,316	19,993	7,377,525
TOTAL FOR DESTINATION	.....		18	2,231	952,284	45,713	16,759,755
	SUBURY	2	2	178	43,528	244	117,804
		4	4	331	210,252	7,631	4,688,782
		5	4	367	91,198	483	238,844
TOTAL FOR DESTINATION	.....		10	878	344,978	8,358	5,045,430
	THUNDER BAY	4	3	263	20,380	523	776,603
		5	2	466	31,401	89	136,032
TOTAL FOR DESTINATION	.....		5	729	51,781	612	912,635
TOTAL FOR ORIGIN	.....		837	66,047	19,973,756	1,280,676	191,754,092
KITCHENER	MONTREAL	2	3	253	25,574	118	76,657
		4	36	3,555	1,229,949	19,897	13,507,642
		5	51	4,274	1,639,732	22,146	15,142,958
		6	18	1,909	357,874	4,751	3,495,366
TOTAL FOR DESTINATION	.....		108	9,993	3,253,129	46,912	32,222,623
	OTTAWA HULL	2	2	356	271,772	11,765	5,850,577
		4	7	597	136,086	4,162	2,073,652
		5	21	3,364	359,760	1,846	937,983
		6	4	931	15,232	22	10,428
TOTAL FOR DESTINATION	.....		34	5,250	781,870	17,795	8,872,600
	OSHAWA	3	1	94	39,359	1,914	292,597
		4	4	3,402	159,331	704	107,608
		5	91	8,932	3,818,490	196,936	30,108,482
		6	4	271	1,870	8	1,058
TOTAL FOR DESTINATION	.....		100	12,700	4,019,050	199,562	30,509,735
	TORONTO	2	23	2,130	801,459	49,290	5,443,412
		3	16	2,612	719,028	93,906	8,898,188
		4	99	15,426	2,421,226	148,201	16,106,103

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ORIGIN	DESTINATION	GRP	RECORD COUNT	ESTIMATED SHIPMENT	ESTIMATED REVENUE	ESTIMATED TONNES	ESTIMATED TONNES-KM
KITCHENER	TORONTO	5	242	28,768	3,468,720	106,349	10,396,406
		6	39	3,502	266,050	10,253	1,085,754
TOTAL FOR DESTINATION	.....		419	52,440	7,696,483	407,999	41,929,863
	HAMILTON	2	4	1,865	408,133	58,844	3,819,421
		3	11	732	115,415	21,394	1,343,064
		4	22	7,714	786,100	89,406	4,354,023
		5	25	7,890	623,882	7,034	439,778
		6	5	459	9,618	67	3,895
TOTAL FOR DESTINATION	.....		67	18,662	1,943,348	176,765	9,960,181
	ST CATHERINES NIAGRA	2	2	376	97,869	2,374	305,645
		3	1	89	17,872	44	5,957
		4	4	217	60,171	8,757	1,044,478
		5	15	8,032	303,345	7,921	903,238
		6	1	2,837	18,766	99	12,946
TOTAL FOR DESTINATION	.....		23	11,553	498,023	19,195	2,272,264
	KITCHENER	2	8	755	178,599	27,428	794,521
TOTAL FOR DESTINATION	.....		8	755	178,599	27,428	794,521
	LONDON	2	2	396	166,334	12,133	1,322,433
		4	12	4,288	167,287	7,504	805,329
		5	32	16,802	477,695	16,793	1,801,374
		6	2	396	58,062	3,437	368,513
TOTAL FOR DESTINATION	.....		48	21,884	869,378	39,867	4,297,649
	WINDSOR	2	7	1,179	1,109,724	14,772	4,255,331
		3	4	65	53,390	4,409	1,423,754
		4	11	534	173,540	11,198	3,262,699
		5	29	16,435	492,026	7,163	2,430,938
TOTAL FOR DESTINATION	.....		51	18,215	1,828,680	37,542	11,372,722
	SUBURY	2	1	168	267,660	4,522	2,081,519
		4	4	675	21,452	32	16,552
		5	12	1,674	268,666	2,264	1,050,356
		6	1	155	13,606	59	27,157
TOTAL FOR DESTINATION			18	2,674	571,384	6,877	3,175,584
	THUNDER BAY	4	2	225	77,301	344	463,934
		5	4	482	59,606	250	336,520

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ORIGIN	DESTINATION	GRP	RECORD COUNT	ESTIMATED SHIPMENT	ESTIMATED REVENUE	ESTIMATED TONNES	ESTIMATED TONNES-KM
TOTAL FOR DESTINATION	.....		6	708	136,907	594	800,454
TOTAL FOR ORIGIN	.....		882	154,837	21,776,651	980,536	146,208,156
LONDON	MONTREAL	2	5	456	31,176	1,512	1,190,099
		4	8	892	168,223	1,569	1,212,103
		5	37	3,659	1,194,062	15,758	11,842,156
		6	17	1,658	1,069,656	14,178	10,360,422
TOTAL FOR DESTINATION	.....		67	6,666	2,463,117	33,017	24,604,780
OTTAWA HULL		2	1	218	8,681	41	23,449
		3	1	16	3,618	2,984	1,728,857
		4	3	330	191,856	4,094	2,372,112
		5	11	2,285	134,705	411	242,237
		6	7	1,767	69,291	219	132,329
TOTAL FOR DESTINATION	.....		23	4,619	408,151	7,749	4,498,984
OSHAWA		4	2	188	7,579	22	5,217
		5	4	324	61,520	664	155,173
		6	1	106	7,054	32	7,466
TOTAL FOR DESTINATION	.....		7	620	76,153	718	167,856
TORONTO		2	18	2,137	552,343	33,831	6,324,759
		3	3	159	59,385	2,657	543,797
		4	25	6,128	585,705	22,110	4,036,783
		5	93	14,109	1,326,269	18,967	3,514,780
		6	66	25,068	1,132,176	40,452	7,597,525
TOTAL FOR DESTINATION	.....		205	47,603	3,655,878	118,017	22,017,644
HAMILTON		2	9	840	126,728	5,973	855,662
		4	4	593	71,500	512	64,200
		5	22	15,763	1,519,472	28,431	3,494,771
		6	7	1,641	544,553	4,812	542,059
TOTAL FOR DESTINATION	.....		42	19,038	2,262,253	39,728	4,956,692
ST CATHERINES NIAGRA		2	1	218	249,981	4,845	943,609
		3	4	335	102,948	12,597	2,473,512
		4	6	334	67,004	10,815	2,132,361
		5	8	866	239,516	2,683	501,589
		6	2	123	1,374	2	306
TOTAL FOR DESTINATION			21	1,879	660,823	30,942	6,051,377
KITCHENER		2	4	455	181,679	4,908	530,347
		4	17	943	100,339	3,923	412,759

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ORIGIN	DESTINATION	GRP	RECORD COUNT	ESTIMATED SHIPMENT	ESTIMATED REVENUE	ESTIMATED TONNES	ESTIMATED TONNES-KM
LONDON	KITCHENER	5	21	18,358	634,650	35,038	3,765,497
		6	6	2,216	553,153	10,445	1,075,797
TOTAL FOR DESTINATION	.....		48	21,973	1,469,871	54,314	5,784,400
	LONDON	2	12	422	49,133	14,658	1,268,135
		3	1	16	2,104	1,468	49,617
		5	1	28	3,366	1,979	60,516
TOTAL FOR DESTINATION	.....		14	466	54,603	18,105	1,378,268
	WINDSOR	2	6	879	558,071	12,189	2,197,081
		3	1	16	9,639	1,067	257,435
		4	12	285	92,041	5,520	1,119,620
		5	27	30,011	475,968	3,853	701,474
		6	11	3,525	46,455	353	63,532
TOTAL FOR DESTINATION	.....		57	34,718	1,182,174	22,982	4,339,142
	SUBURY	2	1	155	15,540	56	33,921
		4	1	81	3,962	3	1,613
		5	9	863	110,453	922	503,958
		6	3	251	14,861	54	29,492
TOTAL FOR DESTINATION	.....		14	1,352	144,816	1,035	568,984
	THUNDER BAY	2	1	33	1,169	472	738,517
		5	1	158	20,998	54	84,318
TOTAL FOR DESTINATION	.....		2	191	22,167	526	822,835
TOTAL FOR ORIGIN	.....		500	139,130	12,400,006	327,133	75,190,962
WINDSOR	MONTREAL	2	19	791	777,912	21,218	19,670,62
		4	10	1,191	131,968	556	561,410
		5	58	4,044	2,419,197	33,876	32,957,026
TOTAL FOR DESTINATION	.....		87	6,027	3,329,077	55,650	53,189,198
	OTTAWA HULL	2	6	401	473,423	11,540	8,782,799
		3	1	238	7,438	24	21,221
		4	4	988	143,370	712	582,487
		5	46	4,973	1,650,283	20,836	16,115,489
		6	1	55	17,552	465	352,918
TOTAL FOR DESTINATION	.....		58	6,656	2,292,066	33,577	25,854,914
	OSHAWA	3	8	378	334,208	30,320	14,455,186
		4	5	433	393,233	15,660	6,729,774
		5	26	5,242	691,674	19,711	8,521,483

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ORIGIN	DESTINATION	GRP	RECORD COUNT	ESTIMATED SHIPMENT	ESTIMATED REVENUE	ESTIMATED TONNES	ESTIMATED TONNES-KH
TOTAL FOR DESTINATION	.....		39	6,055	1,619,315	65,691	29,705,443
WINDSOR	TORONTO	2	24	1,537	667,219	29,639	10,861,396
		3	12	410	248,071	26,658	9,703,518
		4	28	2,100	779,611	34,525	12,786,223
		5	291	32,276	6,374,387	139,364	51,819,381
		6	28	1,396	709,654	36,920	13,414,693
TOTAL FOR DESTINATION	.....		393	37,722	8,778,942	267,306	98,585,211
	HAMILTON	2	2	207	86,109	6,824	2,436,983
		3	5	294	215,717	19,786	6,019,136
		4	4	320	113,258	13,706	5,439,476
		5	23	3,799	777,298	24,693	7,624,065
TOTAL FOR DESTINATION	.....		34	4,621	1,192,382	65,209	21,519,660
	ST CATHERINES NIAGRA	2	3	148	76,556	1,903	712,717
		3	14	713	549,425	55,164	19,717,211
		4	6	718	1,090,266	45,520	16,262,770
		5	22	4,763	565,462	12,263	4,491,521
TOTAL FOR DESTINATION	.....		45	6,344	2,281,709	114,850	41,184,219
	KITCHENER	2	3	226	117,592	7,315	2,256,399
		3	1	16	9,543	1,146	387,115
		4	2	174	37,586	2,137	618,637
		5	19	4,628	702,945	13,468	4,420,209
TOTAL FOR DESTINATION	.....		25	5,045	867,466	24,066	7,682,360
	LONDON	2	8	730	395,062	23,741	4,345,737
		4	2	316	37,186	193	34,515
		5	24	10,412	856,980	17,901	3,297,635
TOTAL FOR DESTINATION	.....		34	11,459	1,289,228	41,835	7,677,887
	WINDSOR	3	3	126	11,909	8,981	674,062
		4	12	871	425,607	50,623	4,191,374
		5	8	1,520	87,304	5,702	477,278
TOTAL FOR DESTINATION	.....		23	2,518	524,820	65,306	5,343,214
	SUSSEX	5	8	701	285,390	2,081	1,515,021
TOTAL FOR DESTINATION			8	701	285,390	2,081	1,515,021
	THUNDER BAY	5	2	521	324,152	2,328	4,063,398

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ORIGIN	DESTINATION	GRP	RECORD COUNT	ESTIMATED SHIPMENT	ESTIMATED REVENUE	ESTIMATED TONNES	ESTIMATED TONNES-KM
TOTAL FOR DESTINATION	.....		2	521	324,152	2,328	4,063,398
TOTAL FOR ORIGIN	.....		738	87,675	22,784,547	737,899	296,320,525
SUBURY	MONTREAL	2	1	203	25,988	129	89,869
		4	2	121	194,618	4,375	3,069,449
		5	7	822	65,985	195	147,113
TOTAL FOR DESTINATION	.....		10	1,147	286,591	4,699	3,306,431
	OTTAWA HULL	4	2	256	122,127	1,487	742,211
		5	2	793	31,316	78	38,598
		6	2	110	4,856	37	17,785
TOTAL FOR DESTINATION	.....		6	1,160	158,299	1,602	798,594
	TORONTO	2	11	655	127,100	1,779	913,338
		3	9	286	108,119	11,328	4,724,290
		4	40	844	442,486	37,172	15,159,219
		5	19	4,647	238,309	6,925	2,763,726
		6	4	286	11,904	188	74,263
TOTAL FOR DESTINATION	.....		83	6,720	1,007,918	57,392	23,634,836
	HAMILTON	4	3	47	37,704	1,725	758,412
		5	2	134	12,193	177	96,097
TOTAL FOR DESTINATION	.....		5	182	49,897	1,902	854,509
	ST CATHERINES NIAGRA	4	4	63	69,278	4,738	2,287,066
TOTAL FOR DESTINATION	.....		4	63	69,278	4,738	2,287,066
	KITCHENER	5	1	128	5,714	13	5,906
TOTAL FOR DESTINATION	.....		1	128	5,714	13	5,906
	LONDON	5	1	9	18,219	126	100,268
TOTAL FOR DESTINATION	.....		1	9	18,219	126	100,268
	WINDSOR	4	1	15	20,367	1,132	823,638
TOTAL FOR DESTINATION	.....		1	15	20,367	1,132	823,638
	SUBURY	4	2	156	54,837	1,413	274,091
		5	6	938	5,277	1,916	1,451,832
		6	1	155	5,665	15	22,838
TOTAL FOR DESTINATION			9	1,250	65,779	3,344	1,748,761

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ORIGIN	DESTINATION	GRP	RECORD COUNT	ESTIMATED SHIPMENT	ESTIMATED REVENUE	ESTIMATED TONNES	ESTIMATED TONNES-KM
SUBURY	THUNDER BAY	4	1	101	58,805	347	353,351
		5	3	266	170,759	421	430,522
TOTAL FOR DESTINATION			4	367	229,564	768	783,873
TOTAL FOR ORIGIN			124	11,046	1,911,626	75,716	34,343,832
THUNDER BAY	MONTREAL	4	6	638	565,452	17,710	29,258,836
		5	1	128	13,849	77	122,902
		6	1	203	6,604	10	17,019
TOTAL FOR DESTINATION			8	970	585,905	17,797	29,398,757
OTTAWA HULL		6	1	128	4,987	13	18,790
TOTAL FOR DESTINATION			1	128	4,987	13	18,790
OSHAWA		4	1	6	7,889	331	462,819
TOTAL FOR DESTINATION			1	6	7,889	331	462,819
TORONTO		1	1	4	12,393	208	292,269
		2	1	168	13,708	76	106,778
		4	50	880	833,523	25,923	36,239,469
		5	28	1,759	388,522	2,705	3,886,461
		6	1	158	5,855	3	4,491
TOTAL FOR DESTINATION			81	2,971	1,254,005	28,915	40,449,488
HAMILTON		4	4	227	349,996	11,535	16,799,210
TOTAL FOR DESTINATION			4	227	349,996	11,535	16,799,210
KITCHENER		4	3	141	266,139	9,347	13,740,928
		5	1	498	25,339	20	26,386
TOTAL FOR DESTINATION			4	639	291,478	9,367	13,767,314
LONDON		2	2	66	47,390	4,056	6,350,912
		4	3	64	67,419	838	1,313,543
		5	2	161	47,694	1,024	1,604,518
TOTAL FOR DESTINATION			7	292	162,503	5,918	9,268,973
WINDSOR		4	1	8	14,859	562	980,766
TOTAL FOR DESTINATION			1	8	14,859	562	980,766
SUBURY		4	2	119	77,919	3,448	3,511,160
		5	1	101	7,149	31	30,978

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ORIGIN	DESTINATION	GRP	RECORD COUNT	ESTIMATED SHIPMENT	ESTIMATED REVENUE	ESTIMATED TONNES	ESTIMATED TONNES-KM
TOTAL FOR DESTINATION			3	221	85,068	3,479	3,542,130
TOTAL FOR ORIGIN			110	5,466	2,756,690	77,917	114,688,255
REPORT GRAND TOTAL			20,907	2,994,139	411,736,830	24,612,493	4,130,086,471

APPENDIX B

STATISTICS CANADA MANUFACTURING MAN-HOURS DATA

The manufacturing man-hours paid stratified by commodity group were obtained from Statistics Canada "Manufacturing Industries of Canada : Sub-Provincial Areas". Tables B.1 to B.5 summarize the data extracted from these reports. The manufacturing man-hours are stratified into the seven major commodity groups listed at the head of the columns. It will be noted that some of the entries in these tables are absent, particularly for some of the smaller population centres where there are one or two dominant industries.

TABLE B.1 Manufacturing Man-Hours Paid by Commodity Group, 1974

	(1) Food, Beverage Tobacco Products	(2) Leather, Textile Knitting Mills Clothing Industry	(3) Wood, Furniture Paper Allied Print Publishing	(4) Machinery, Transport Equip. Electrical Prod.	(5) Primary Metal Metal Fabricating	(6) Rubber & Plastic Petroleum, Coal Chemical Products	(7) Non-Metallic Mineral Products Miscellaneous Other Major Groups	Total
Ottawa-Hull	2,297,000	1,003,000	13,918,000	6,789,000	1,488,000	940,000	3,956,000	30,391,000
Oshawa		6,000		169,000			36,933,000	37,108,000
Toronto	47,315,000	54,671,000	89,901,000	132,127,000	76,337,000	44,535,000	60,538,000	505,424,000
Hamilton	7,316,000	7,238,000	6,074,000	18,632,000	63,364,000	4,446,000	6,068,000	113,138,000
St. Cath.-N. F.	3,864,000	2,727,000	6,743,000	26,554,000	20,294,000	3,148,000	6,359,000	69,689,000
Kitchener	8,995,000	11,135,000	6,776,000	24,727,000	12,183,000	9,344,000	7,791,000	80,951,000
London	6,364,000	1,162,000	5,278,000	26,970,000	3,711,000	2,129,000	3,701,000	49,315,000
Windsor	4,234,000		1,195,000	40,030,000	7,541,000	1,629,000	6,386,000	61,015,000
Sudbury	484,000		267,000		191,000		14,481,000	15,423,000
Thunder Bay	933,000		7,627,000		476,000		3,475,000	12,511,000
Montreal	43,119,000	136,455,000	64,137,000	71,083,000	59,104,000	25,390,000	42,032,000	441,320,000

TABLE B.2 Manufacturing Man-Hours Paid by Commodity Group, 1975

	(1) Food, Beverage Tobacco Products	(2) Leather, Textile Knitting Mills Clothing Industry	(3) Wood, Furniture Paper Allied Print Publishing	(4) Machinery, Transport Equip. Electrical Prod.	(5) Primary Metal Metal Fabricating	(6) Rubber & Plastic Petroleum, Coal Chemical Products	(7) Non-Metallic Mineral Products Miscellaneous Other Major Groups	Total
Ottawa-Hull	2,198,000	1,140,000	5,904,000	1,562,000	1,379,000		15,453,000	27,636,000
Oshawa		6,000		169,000			36,933,000	37,108,000
Toronto	48,022,000	57,000,000	87,139,000	127,143,000	73,329,000	46,050,000	60,850,000	499,533,000
Hamilton	6,886,000	6,104,000	5,648,000	18,268,000	59,232,000	5,546,000	6,420,000	108,104,000
St. Cath. - N. P.	4,141,000	2,543,000	5,030,000	24,135,000	19,597,000	3,132,000	5,904,000	64,482,000
Kitchener	9,099,000	10,785,000	6,276,000	21,208,000	15,156,000	8,915,000	5,796,000	77,235,000
London	6,650,000	2,125,000	4,965,000	22,058,000	2,420,000	2,329,000	2,663,000	43,210,000
Windsor	4,556,000	165,000	1,722,000	38,471,000	6,943,000	2,149,000	4,988,000	58,994,000
Sudbury	528,000	13,000	255,000		784,000		9,226,000	10,806,000
Thunder Bay	864,000		5,213,000		495,000		3,245,000	9,817,000
Montreal	43,768,000	137,973,000	56,628,000	72,681,000	57,432,000	25,727,000	47,858,000	442,067,000

TABLE B.3 Manufacturing Man-Hours Paid by Commodity Group, 1976

	① Food, Beverage Tobacco Products	② Leather, Textile Knitting Mills Clothing Industry	③ Wood, Furniture Paper Allied Print Publishing	④ Machinery, Transport Equip. Electrical Prod.	⑤ Primary Metal Metal Fabricating	Rubber & Plastic Petroleum, Coal Chemical Products	⑥ Non-Metallic Mineral Products Miscellaneous Other Major Groups	⑦ Total
Ottawa-Hull	2,179,000	355,000	12,421,000	5,045,000		804,000	6,201,000	27,005,000
Oshawa		6,000		169,000			36,933,000	37,108,000
Toronto	47,238,000	55,708,000	85,855,000	74,708,000	122,720,000	47,192,000	58,633,000	492,054,000
Hamilton	5,788,000	6,595,000	5,195,000	17,309,000	61,026,000	6,569,000	6,458,000	108,940,000
St. Cath.-N.F.	3,998,000	2,381,000	5,357,000	24,630,000	17,374,000	1,969,000	6,632,000	62,341,000
Kitchener	9,397,000	12,819,000	5,992,000	21,474,000	15,164,000	9,843,000	6,227,000	80,916,000
London	6,850,000	2,003,000	3,919,000	8,513,000	2,575,000	2,340,000	6,477,000	32,677,000
Windsor	3,693,000		1,300,000	41,473,000	7,630,000	908,000	6,369,000	61,373,000
Sudbury	467,000		268,000				11,512,000	12,906,000
Thunder Bay	865,000		12,769,000	183,000			2,225,000	16,649,000
Montreal	44,651,000	32,354,000	60,837,000	66,128,000	53,258,000	25,811,000	40,044,000	423,083,000

TABLE B.4 Manufacturing Man-Hours Paid by Commodity Group, 1977

	1	2	3	4	5	6	7	Total
	Food, Beverage Tobacco Products	Leather, Textile Knitting Mills Clothing Industry	Wood, Furniture Paper Allied Print Publishing	Machinery, Transport Equip. Electrical Prod.	Primary Metal Metal Fabricating	Rubber & Plastic Petroleum, Coal Chemical Products	Non-Metallic Mineral Products Miscellaneous Other Major Groups	
Ottawa-Hull	2,192,000	991,000	12,141,000	2,611,000	1,862,000	957,000	4,227,000	24,981,000
Oshawa		6,000		169,000			36,933,000	37,108,000
Toronto	46,399,000	53,862,000	82,278,000	117,810,000	71,583,000	46,541,000	53,254,000	471,727,000
Hamilton	5,564,000	6,584,000	5,469,000	16,398,000	60,074,000	3,315,000	8,619,000	106,023,000
St. Cath.-N.F.	4,024,000	1,986,000	6,026,000	27,956,000	16,997,000	2,046,000	6,490,000	65,525,000
Kitchener	9,827,000	10,687,000	5,813,000	20,276,000	14,651,000	10,132,000	6,845,000	78,231,000
London	6,475,000	1,670,000	3,559,000	7,861,000	3,786,000	2,163,000	5,250,000	30,764,000
Windsor	3,476,000		1,031,000	44,215,000	8,486,000		8,178,000	65,386,000
Sudbury	436,000		197,000		816,000		11,304,000	12,753,000
Thunder Bay	852,000		8,113,000		644,000		3,175,000	12,784,000
Montreal	43,415,000	118,661,000	55,547,000	64,565,000	48,142,000	17,152,000	45,678,000	393,160,000

TABLE B.5 Manufacturing Man-Hours Paid by Commodity Group, 1978

	① Food, Beverage Tobacco Products	② Leather, Textile Knitting Mills Clothing Industry	③ Wood, Furniture Paper Allied Print Publishing	④ Machinery, Transport Equip. Electrical Prod.	⑤ Primary Metal Metal Fabricating	Rubber & Plastic Petroleum, Coal Chemical Products ⑥	Non-Metallic Mineral Products Miscellaneous Other Major Groups ⑦	Total
Ottawa-Hull	1,737,000	1,080,000	13,251,000	3,040,000	2,301,000	1,010,000	4,676,000	27,095,000
Oshawa		6,000		169,000			36,933,000	37,108,000
Toronto	49,561,000	56,199,000	87,270,000	130,760,000	65,520,000	53,581,000	65,100,000	507,991,000
Hamilton	5,864,000	7,863,000	5,332,000	15,468,000	64,157,000	3,248,000	8,450,000	110,382,000
St. Cath.-N.F.	3,774,000	2,093,000	5,940,000	27,984,000	7,612,000	964,000	13,105,000	61,472,000
Kitchener	9,613,000	8,275,000	5,640,000	22,666,000	13,035,000	10,396,000	11,842,000	81,467,000
London	6,755,000	1,118,000	4,028,000	8,710,000	4,296,000	2,024,000	7,632,000	34,563,000
Windsor	2,990,000		1,537,000	42,485,000	9,645,000	1,364,000	7,537,000	65,558,000
Sudbury	385,000				578,000		6,230,000	7,193,000
Thunder Bay			8,691,000		787,000		4,023,000	13,501,000
Montreal	44,392,000	117,799,000	57,992,000	44,748,000	40,654,000	7,471,000	93,382,000	406,438,000

APPENDIX C

ADDITIONAL ANALYSES OF COMMODITY ATTRACTION AND GENERATION DATA

A variety of regression equations were estimated and evaluated in an attempt to relate commodity attractions and generations by for-hire trucks to the manufacturing composition of each area. The small number of independent observations constrained the number of valid alternatives. Only two equation forms were reasonable and these were in terms of (i) total manufacturing man-hours, and (ii) manufacturing man-hours stratified into light and heavy industry.

Table C.1 summarizes the attraction regression equations developed using total manufacturing man-hours as the independent variable while Table C.2 lists the residuals associated with the regression equations for the five years for which for-hire truck survey data are available.

Table C.1 indicates that the regression coefficients are all significant at the 1% level and the coefficients of determination are all high. The regression coefficients are relatively stable over the survey years since 1975 and vary from 0.025 to 0.032 tonnes shipped by for-hire trucks per manufacturing man-hour. The use of manufacturing man-hours as the independent variable creates some difficulties as the commodity tonnes shipped by for-hire trucks that are attracted to a community include manufacturing inputs, as well as inputs to other employment sectors and consumer goods. The previous analyses of the independent variables would suggest that attractions to Ottawa might be under-estimated. The analyses also suggested that population could not be included as a second independent variable in order to reflect these other sources of consumption.

The residuals summarized in Table C.2 indicate that attractions to Ottawa-Hull and Hamilton in 1978 were substantially

TABLE C.1 Attraction Regression Equations Using Total Man-Hours

Year	a	b	t	Significance Level	r^2	s_e
1974	463,906	0.018	10.2	1%	0.929	7.7×10^5 tonnes
1975	362,953	0.026	16.7	1%	0.972	6.8×10^5 tonnes
1976	-138,525	0.032	26.9	1%	0.989	5.1×10^5 tonnes
1977	-215,016	0.032	17.7	1%	0.975	7.4×10^5 tonnes
1978	311,799	0.025	25.3	1%	0.988	4.4×10^5 tonnes

Commodity attraction = $a + b$ (Total Man-Hours)

TABLE C.2 Residuals for Regression Equations of Table C.1

	1974	1975	1976	1977	1978
Ottawa-Hull	344,316	219,620	838,415	1,290,171	735,232
Oshawa	-248,311	-444,272	-161,366	6,829	66,058
Toronto	-231,578	78,223	127,586	286,737	-2,954
Hamilton	1,623,302	731,679	48,782	-500,665	403,307
St.Cath.-N.F.	-493,418	-292,898	-9,038	124,521	286,323
Kitchener	-802,667	-1,454,965	-1,090,653	-1,471,267	-455,252
London	-65,531	396,320	223,761	168,936	-4,356
Windsor	774,354	-24,431	-61,208	-270,051	-611,766
Sudbury	-428,881	59,525	235,468	290,731	5,484
Thunder Bay	-471,585	731,199	-151,746	73,743	-422,122

TABLE C.3 Attraction Regression Equations Using Light/Heavy Man-Hours

Year	a	b ₁	b ₂	t ₁	t ₂	Significance Level	r ²	s _e
						b ₁	b ₂	
1974	19,789	-0.004	0.038	-0.4	4.0	Not @ 50%	1%	0.958 6.0 x 10 ⁵ tonnes
1975	283,062	0.022	0.030	1.7	2.4	20%	5%	0.973 6.7 x 10 ⁵ tonnes
1976	-109,522	0.033	0.030	4.2	4.0	1%	1%	0.989 5.1 x 10 ⁵ tonnes
1977	-28,100	0.041	0.023	4.0	2.3	1%	10%	0.978 7.0 x 10 ⁵ tonnes
1978	325,278	0.026	0.024	3.9	3.8	1%	1%	0.988 4.4 x 10 ⁵ tonnes

Commodity Attraction = a + b₁ (Light Man-Hours) + b₂ (Heavy Man-Hours)

under-estimated, while those to Kitchener, Windsor and Thunder Bay were substantially over-estimated. The under-estimation for Ottawa is clearly related to its atypical economic base which contains little manufacturing employment. While the under-estimation of Hamilton may be related to its concentration of manufacturing in heavy industries. The over-estimation of Kitchener and Windsor are related to their specialization in manufacturing with their higher than average per capita manufacturing man-hours tending to produce these over-estimations.

Tables C.3 and C.4 summarize the information for the regression equations developed in terms of the two independent variables which express manufacturing man-hours separately in terms of light and heavy industries. Table C.3 indicates that the stratification of manufacturing man-hours had little impact on the quality of the regression equations. In fact, not all of the partial regression coefficients are statistically significant. The coefficients of determination and standard errors of the estimate improved marginally and Table C.4 illustrates that there was little impact on the residuals.

Tables C.5 and C.6 summarize the regression equations developed for annual commodity generations carried by for-hire trucks in terms of total manufacturing man-hours. While the regression coefficients are all statistically significant at the 1 percent level, the standard error of the estimate is large for all five equations, and this is reflected in the residuals presented in Table C.5. The regression equations are relatively stable and suggest commodity generation rates of 0.025 to 0.029 tonnes per manufacturing man-hour.

Tables C.7 and C.8 summarize the regression equations developed in terms of light and heavy manufacturing man-hours as independent variables. Table C.7 indicates that these multiple regression equations are of inadequate statistical quality while Table C.8 illustrates that there is no significant change in the pattern of residuals.

TABLE C.4 Residuals for Regression Equations of Table C.3

	1974	1975	1976	1977	1978
Ottawa-Hull	941,428	267,105	801,366	1,032,761	717,160
Oshawa	-564,372	-501,380	-133,426	151,476	75,726
Toronto	-43,966	108,682	112,651	182,598	-9,930
Hamilton	820,202	594,605	111,160	-117,644	430,622
St.Cath.-N.F.	-773,225	-339,252	14,607	269,171	295,124
Kitchener	-468,693	-1,395,591	-1,114,965	-1,616,821	-460,606
London	5,997	437,744	197,452	6,773	-13,799
Windsor	269,669	-97,653	-14,536	46,129	-591,753
Sudbury	-268,733	105,507	223,968	206,379	-3,991
Thunder Bay	81,868	820,637	-198,017	-160,674	-438,118

TABLE C.5 Generation Regression Equations Using Total Man-Hours

Year	a	b	t	Significance Level	r ²	s _e
1974	317,427	0.016	9.5	1%	0.918	7.5 x 10 ⁵ tonnes
1975	-57,274	0.025	14.4	1%	0.963	7.7 x 10 ⁵ tonnes
1976	182,689	0.026	8.8	1%	0.906	1.3 x 10 ⁶ tonnes
1977	-177,971	0.029	11.0	1%	0.938	1.1 x 10 ⁶ tonnes
1978	158,233	0.024	9.9	1%	0.925	1.1 x 10 ⁶ tonnes

Commodity Generations = a + b (Total Man-Hours)

TABLE C.6 Residuals for Regression Equations of Table C.5

	1974	1975	1976	1977	1978
Ottawa-Hull	-161,874	632,348	76,894	568,342	-8,940
Oshawa	-160,830	-134,917	-394,892	-222,031	-489,366
Toronto	-233,651	-13,502	-238,328	-97,331	-258,003
Hamilton	1,736,208	1,331,720	3,031,712	2,300,248	2,676,270
St.Cath.-N.F.	152,525	-433,169	-489,218	-407,366	89,321
Kitchener	-930,479	-1,301,005	-1,410,366	-1,510,371	-1,284,778
London	449,978	441,657	-299,639	141,214	-120,494
Windsor	-285,066	-718,383	-866,040	-1,019,373	-647,014
Sudbury	-355,307	107,030	900,307	156,616	101,898
Thunder Bay	-221,505	88,222	-127,740	89,725	-58,456

TABLE C.7 Generation Regression Equations Using Light/Heavy Man-Hours

Year	a	b ₁	b ₂	t ₁	t ₂	Significance Level	r ²	s _e
						b ₁	b ₂	
1974	-109,430	-0.005	0.036	-0.5	3.8	Not @ 50%	1%	5.8 x 10 ⁵ tonnes
1975	-253,789	0.016	0.035	1.1	2.5	30%	5%	7.4 x 10 ⁵ tonnes
1976	-202,057	0.005	0.046	0.3	2.7	Not @ 50%	5%	1.2 x 10 ⁶ tonnes
1977	-372,385	0.019	0.038	1.3	2.6	30%	5%	1.0 x 10 ⁶ tonnes
1978	-255,301	0.005	0.043	0.3	3.0	Not @ 50%	2%	9.7 x 10 ⁵ tonnes

Commodity Generation = a + b₁ (Light Man-Hours) + b₂ (Heavy Man-Hours)

TABLE C.8 Residuals for Regression Equations of Table C.7

	1974	1975	1976	1977	1978
Ottawa-Hull	412,034	749,146	568,469	836,094	545,945
Oshawa	-464,603	-275,404	-765,391	-372,460	-785,476
Toronto	-53,287	61,359	-38,310	11,283	-36,402
Hamilton	964,333	994,519	2,204,648	1,901,924	1,839,857
St.Cath.-N.F.	-106,399	-547,206	-802,646	-557,781	-179,794
Kitchener	-609,477	-1,155,853	-1,087,538	-1,358,930	-1,119,312
London	518,731	543,543	49,500	309,901	169,736
Windsor	-770,129	-818,512	1,484,931	-1,348,200	1,260,050
Sudbury	-201,381	220,135	870,231	244,358	392,701
Thunder Bay	301,439	308,220	486,134	333,554	432,515